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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

WASHINGTON MEETING

AT

WASHINGTON, D. C.

April 28–30, 1949

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APRIL 28, 1949 Vol. 24, No. 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 28–29–30, 1949

THE **1949 Washington Meeting** of the American Physical Society, 292nd of the series, will very completely fill the days of Thursday, Friday, and Saturday, April 28th, 29th, and 30th, 1949. Thanks to the efforts of the Washington Local Committee, the apprehension that the halls would be too few was finally made groundless. This however took much time, during which the summons card was held back in the fear that a drastic limitation would have to be imposed; and the eventual interval from summons card to deadline date had to be made distinctly shorter than is usual. Whether or not this circumstance be responsible for the fact that this Washington meeting is smaller in size than the last one, regrets are expressed to those of our members who may have found the interval too short to allow them to submit intended papers. The halls range widely over what was already described, a century before the Society was founded, as "the city of magnificent distances." There will be sessions at George Washington University, the National Academy of Sciences, the National Bureau of Standards, and in three auditoriums of the Federal Government (Department of Commerce Auditorium, Department of Interior Auditorium, Departmental Auditorium) which we are enabled to enjoy because the Office of Naval Research and the National Bureau of Standards are co-sponsors of our meetings.

Location of the halls. Hall of Government of George Washington University is at the northwest corner of 21st and G streets. The National Academy of Sciences is on Constitution Avenue between 21st and 22nd streets. The Department of Interior Auditorium is on C Street between 18th and 19th streets; the Department of Commerce Auditorium is on 14th Street between E Street and Constitution Avenue; the Departmental Auditorium is on Constitution Avenue (north side) between 12th and 14th streets. The National Bureau of Standards is on Connecticut Avenue at Van Ness Street; it may be reached by buses marked L-2 and L-4 which start from the southeast corner of Pennsylvania Avenue and 13th Street, making the distance in half-an-hour. (For completeness the letters N.W. should be affixed to all the street names given above.)

The registration desk will be in the lobby of the Department of Commerce. Even those whose interests call them to other buildings are asked to register there.

A **Symposium on Spectroscopy and Molecular Structure,** arranged with the aid of R. S. Mulliken and presented under the joint sponsorship of the Office of Naval Research and the American Physical Society, will be held on Thursday morning and afternoon in the Department of Interior Auditorium. The four papers of the morning session will constitute as many surveys of broad divisions of the topic; the five of the afternoon are devoted to more limited subjects.

A **Symposium on Selected Topics of Nuclear Physics** (the selection-principle excluded cosmic rays and mesons) will be held under the joint sponsorship of the Office of Naval Research and the American Physical Society on Friday morning and afternoon in the Department of Interior Auditorium. Mainly, but not altogether, this Symposium derives from a conference held at Chicago in December, to which no general invitation was extended.

A **Symposium on Atomic Frequency and Time Standards,** arranged with the aid of Harold Lyons and Polycarp Kusch, will be held on Saturday morning in the Department of Commerce Auditorium.

Invited papers on the general programme are by L. W. Alvarez, F. J. Dyson, L. Marton, A. M. J. F. Michels, E. M. Purcell, and R. Serber.

APR 18 1949

One hundred and ninety-five **contributed papers** are distributed among eighteen sessions.

The **banquet** of the American Physical Society will be held at seven o'clock on Thursday evening in the Ballroom of the Mayflower Hotel (same place as last year). The price of the tickets is five dollars, and it is particularly requested that our members make advance reservation by use of the form printed on the inside back cover of this Bulletin and *send their checks with the form.* Presumably there will be a few unbespoken tickets available at the registration desk on Thursday morning, but this cannot be guaranteed. The after-dinner speaker will be E. U. Condon, National Bureau of Standards, and there will be chamber music after the speech.

The annual **Sigma Pi Sigma luncheon** will be held on Friday at 12:30 P.M. in the Roger Smith Hotel (Pennsylvania Avenue and 18th Street, N.W.), at the price of $1.50. Tickets should be booked in advance by writing to Dr. Marsh W. White, Pennsylvania State College, State College, Pennsylvania; some may be available at the registration desk up to 10 A.M. on Thursday.

The **Nominating Committee** of the American Physical Society will assemble at 4:30 P.M. on Friday in Room 301, South Building, National Bureau of Standards. This Committee consists of J. R. Oppenheimer (*Chairman*), Walker Bleakney, R. M. Bozorth, P. W. Bridgman, J. W. Liska, W. B. Nottingham, V. Rojansky, J. T. Tate, and M. A. Tuve.

The **Council** of the American Physical Society will meet at 9:30 A.M. on Saturday in Room 301, South Building, National Bureau of Standards.

Hotels. A large number of rooms was guaranteed to our members by the Raleigh, Shoreham, Wardman Park, Washington, and Willard Hotels. This is mentioned for the sake of the record chiefly: by the time this Bulletin appears, these rooms should all be booked, and dilatory members ought not to be surprised if they have to seek elsewhere.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on January 30, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of additional papers of which the abstracts reach the office of the Society not later than Friday 22 April." Do not regard this as a guarantee! the idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are thus accepted (if any are) will not be published. They will be scheduled for Saturday afternoon at the end of Session Y, and will be announced on a blackboard at the registration desk.

Prospective meetings of the Society are planned as follows: Cambridge, Massachusetts, June 16–18 (Semi-Centennial Meeting); Seattle, Washington, June 27–29.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of an invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session is indicated, at the end of which it may be offered: but the presiding officer of the session may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Washington meeting of 1949 are given in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proof-reading is always cursory because of the need for haste; but the authors have opportunity to correct their proofs before the abstracts appear in the *Physical Review.* Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before amputating the abstracts to fit the requirements stated on the summons card. Speakers should not forget to retrieve their slides before they leave the rooms where the slides have been shown; the Local Committee is in no wise obligated to keep or to return them.

The Council decided at its January meeting to discontinue the republication of abstracts in the *Physical Review.* This change of policy will not however go into effect until later in the year.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE MEETING

(Personal names are those of invited speakers.)

Thursday Morning

A. Apparatus of nuclear physics; gyromagnetic ratios; E. M. Purcell. Commerce.
B. Cosmic rays. Departmental Auditorium.
C. Heat and cold. Bureau.
E. Symposium on spectroscopy and molecular structure: W. F. Meggers, G. Herzberg, R. S. Mulliken, C. H. Townes. Interior.

Thursday Afternoon

F. Symposium on spectroscopy and molecular structure, concluded: H. C. Longuet-Higgins, B. L. Crawford, D. F. Hornig, D. H. Rank, Michael Kasha. Interior.
G. Reactions of transmutation. Commerce.
H. Cosmic rays, mostly penetrating particles; F. J. Dyson. Departmental Auditorium.
I. A. M. J. F. Michels; fluid dynamics; x-rays. Bureau.

Thursday Evening

Banquet of the American Physical Society; E. U. Condon. Mayflower Hotel.

Friday Morning

K. Spectroscopy, atomic and molecular. Bureau.
L. Solid-state physics, including magnetism. Commerce.
N. Symposium on selected topics in nuclear physics; H. A. Bethe, R. G. Herb, C. L. Critchfield, R. F. Christy, Thomas Lauritsen. Interior.

Friday Afternoon

O. Symposium on selected topics in nuclear physics, *concluded:* L. J. Rainwater, E. P. Wigner, M. G. White *et al.*, A. C. G. Mitchell, E. C. Pollard. Interior.
P. Molecular spectroscopy. Bureau.
Q. Solid-state physics, mostly semi-conductors. Commerce.
R. L. Marton; electron optics. Departmental Auditorium.
RA. L. W. Alvarez, Robert Serber. Departmental Auditorium.

Saturday Morning

S. Symposium on atomic frequency and time standards: G. Gamow, G. H. Clemence, P. Sollenberger, H. Lyons, C. H. Townes, P. Kusch. Commerce.
T. Nuclear masses; fission; reactions of transmutation involving electrons and gamma-rays. Departmental Auditorium.
U. Beta- and gamma-emitters, I. National Academy.
V. Theoretical Physics, I. Hall of Government, 1.

Saturday Afternoon

W. Beta- and gamma-emitters, II. National Academy.
X. Neutrons. Departmental Auditorium.
Y. Electron physics; post-deadline papers, if any. Commerce.
Z. Theoretical physics, II. Hall of Government, 1.

PROGRAMME

THURSDAY MORNING AT 10:00

Department of Commerce Auditorium

(M. A. TUVE presiding)

Apparatus of Nuclear Physics; Gyromagnetic Ratios

A1. The Design and Construction of the Cornell Synchrotron.* BOYCE D. MCDANIEL, JOHN W. DEWIRE, DALE R. CORSON, AND ROBERT R. WILSON, *Cornell University.*—The synchrotron is designed to accelerate electrons to 300 Mev. Its circular magnetic guide field is provided by 24 *C* shaped laminated magnetic yokes. These are located radially on an orbit radius of 1 meter with the gaps facing inward. The glass-walled vacuum chamber provides a usable aperture of $5'' \times 1\frac{3}{4}''$. Electrons are initially accelerated by betatron action that is produced by magnetic shunts which bridge the gaps of the *C* sections. These shunts begin to saturate when the electrons have reached 2 Mev and at this time the synchrotron cavity resonator is turned on. The resonator is a shorted quarter-wave coaxial line in which the vacuum wall serves as the dielectric between the inner and outer conductor. Corning Type 707 glass is used for the wall in the resonator and the conducting surfaces are formed by laminated electro-plated silver. The magnet is excited at 60 c.p.s. by a synchronous motor-generator set and is resonated with a condenser bank. Because of the non-linearity of the magnetic circuit, a variable reactor is used in parallel with the generator to maintain a unity power factor load while the magnet is being raised to full excitation.

* Supported by the ONR.

A2. Initial Performance of the Cornell Synchrotron.* D. R. CORSON, C. P. BAKER, J. W. DEWIRE, B. D. MCDANIEL, C. D. SWARTZ, R. L. WALKER, R. R. WILSON, AND W. M. WOODWARD, *Cornell University.*—The Cornell synchrotron has been in operation since January 3, 1949, with a maximum electron energy of 120 Mev. Numerous unforeseen problems had to be solved before the betatron action operated properly. Foremost among these were radially dependent phase shifts in the magnet gap flux which produced an incorrect radial dependence of the flux at injection time. This trouble has been minimized with controllable currents in annular correction coils located in the gap. Azimuthal phase variations are corrected by windings arranged on the magnet *C*'s so as to permit first, second, and third azimuthal harmonic corrections to be made. Our flux bar design proved to be more than adequate and flux measurements served to locate the betatron orbit within the donut. The betatron beam was first found, after six weeks of searching, with an internal scintillation detector. The synchrotron beam, first detected with the same arrangement, has been maximized with external detectors. Sparking and heating in the r-f resonator limit our electron energy to its present value. The pressure, measured with an ionization gauge near one pump, must be less than about 5×10^{-5} mm before the betatron beam can be accelerated. The visible radiation from the electron beam has been observed.

* Supported by the ONR.

A3. Magnetic Measurements on the M. I. T. 300-Mev Electron Synchrotron.* J. S. CLARK, W. W. DRAKE, C. Y. TSAO, *Massachusetts Institute of Technology.*—The measurements fall into three main categories: (1) the fulfillment of the requirements of the equation $\phi = 2\pi R_0^2 B_0$ during the early part of the cycle, (2) the shaping of the magnetic field in accordance with $B = B_0(r_0/r)^n$ where $0.5 < n < 1.0$ throughout the first quarter cycle, and (3) the limitation of the azimuthal variation. Transients which occur during the first part of the cycle under pulsed operation necessitate back-biasing of 75 gauss. The conditions required by (1) above are met by shimming of the flux bars on each pole and by adjustment of the current in windings enclosing all the flux bars. The value of n is determined by the use of peaking strips and bucking matched coils; the former yielding value during the first 30 microseconds. Correction of n is accomplished by forcing current through concentric wires spaced one inch apart in the gap.

* Assisted by the joint program of the ONR and the AEC.

A4. Shielding Material for High Energy Accelerators. E. CREUTZ, *Carnegie Institute of Technology.*—Desirable properties of material in radiation shields for high energy nuclear particle accelerators include (1) high density, (2) high atomic weight, (3) appreciable hydrogen content, and (4) low cost. Most accelerators are shielded with rather standard concrete, emphasizing (4) above (1), (2), and (3). Concrete containing only magnetite concentrate, cement, and water can have density of 200 lbs. per cu. ft., 3000 lbs. per sq. in., 28-day compressive strength, and 10 percent moisture. Effect is to reduce over-all cost of project because of space saved. Moisture content drops to 2 percent with indoor exposure. Diffusivity of moisture has been measured and methods of reducing moisture loss studied.

A5. Ceramic Materials for Synchrotron Vacuum Tubes.* J. E. THOMAS, JR., W. M. SHAKESPEARE, JR., B. COHEN, R. B. PATTERN, AND V. P. HENRI, *Massachusetts Institute of Technology.*—Several ceramic bodies composed of talc, clay, and titanates, suitable for slip casting or dry pressing, have been developed. Method of kiln setting is critical in preventing deformation during firing. Firing temperatures are near 1200°C. The resultant ceramics are vacuum tight. Their rupture modulus is about 17,000 p.s.i. Dielectric constants vary from 7.3 to 18.5 depending on titania content, with loss tangents less than 0.001 at 45 mc. The tube for the M.I.T. Synchrotron is made in twelve sections. The ends are precision machined with water cooled diamond tools and joined with thermoplastic resin cement (Vinylite Solution T-24-9, Bakelite Corporation). Cemented joints are as strong as the ceramic and do not leak, if adjacent surfaces are parallel to within 0.001 in. The r-f resonator is one of the twelve sections. Material of dielectric constant 9.0 is used. Several successive coats of a fired-on silver compound (Silver Paste 4731, E. I. Du Pont) are applied. After the silver has been laminated to reduce 60-cycle eddy currents, observed "*Q*" varies between 375 and 450, in good agreement with theory.

* Assisted by the joint program of the ONR and the AEC.

A6. Fast Electron Tracks in Nuclear Emulsions. W. VAN DER GRINTEN, *General Electric Company.*—Photomicrographs of electron tracks in the 0.5–50-Mev region, using experimental

NTB3 emulsions and standard methods of processing will be presented. Electron energies were determined from multiple scattering data and in some cases from magnetic deflections. Grain counts can be made at all energies including those producing minimum ionization. Preliminary measurements on the variation of grain density with electron energy will be discussed.

A7. Automatic Grain Counting of Tracks in Nuclear Emulsions. P. V. C. HOUGH, *Cornell University.*—An instrument has been developed which records the density of tracks in nuclear emulsions as a function of residual range. Results are closely comparable with those of visual counting, with the advantages of considerably greater ease and complete objectivity. A microscope, used at magnification 760×, images at the photo-cathode of a photo-multiplier a rectangle about $\frac{3}{4}\mu \times 12\mu$ at the emulsion (wider for measuring tracks of heavy nuclei) which is made optically to rotate, and oscillate along a line normal to the track, while the track is driven longitudinally past the microscope at 240μ/min. In this way the observer needs only to adjust the focus and make gross changes in lateral position in counting a track. A background which is higher than in visual counting due to greater depth of focus at present limits measurement to tracks of density greater than about $\frac{1}{2}$ grain per micron, but there is no restriction at the high grain density end as with visual counting. Background grain density is automatically subtracted and the variations in the background recorded so that spurious variation in track density of this origin may be assessed. Quantitative results will be presented.

A8. Corrections to the Range-Energy Curves for Alpha-Particles and Protons. WILLIAM P. JESSE AND JOHN SADAUSKIS, *Argonne National Laboratory.*—A preliminary measurement of the ratio of the total ionization for the individual alpha-particles from samarium and polonium in argon and in air shows the ratio Sm/Po to be about 5 percent less in air. If we assume a fairly constant proportionality between alpha-ionization and alpha-particle energy in argon, these results would indicate a distinct lack of such proportionality in air. Since the alpha-range-energy curves in current use are in reality range-ionization in air curves, one can explain why such curves give too low energy values corresponding to measured ranges in the region 1–3 Mev, as in the reaction $B^{10}(n, \alpha)Li^7$. From our results corrections have been applied in this region to the Halloway-Livingston curve. The corrected curve agrees much better with experimental data. Since above 0.3 Mev the Livingston-Bethe proton range-energy curve was derived, with some uncertainties, from the alpha-curve, any change in the latter necessitates a change in the former. The corrected proton curve is slightly higher in energies than the old one, the correction, for instance, being about 20 kev for range 1 cm.

A9. Further Data on the Spin Gyromagnetic Ratio of the Electron. A. K. MANN AND P. KUSCH, *Columbia University.*—The atomic beam magnetic resonance method has been used to compare the g_J values of In in the $^2P_{3/2}$ and $^2P_{1/2}$ states in order to obtain a value of the spin gyromagnetic ratio of the electron.* For this purpose new measurements of the magnetic dipole and electric quadrupole interaction constants of the $^2P_{3/2}$ state were made. The determination of the g_J ratio involved only the measurement of frequencies of lines in the h.f.s. spectra of both states at constant magnetic field. Lines with widely different frequency dependence on field were selected to avoid systematic errors arising from inhomogeneities in the field. The result of these measurements is $g_J(^2P_{3/2})/g_J(^2P_{1/2}) = 2(1.00200 \pm 0.00006)$. Assuming Russell-Saunders coupling, and $g_L = 1$, the spin gyromagnetic ratio of the electron may be calculated. The result is $g_s = 2(1.00133 \pm 0.00004)$, which is to be compared with the value $g_s = 2(1.00119 \pm 0.00005)$ obtained by Kusch and Foley. The discrepancy is greater than the sum of the experimental errors. The $^2P_{1/2}$ state of In is believed to be free of significant perturbations which might affect the total electronic g value. However, in view of possible perturbations of the $^2P_{3/2}$ state, the agreement must be considered as very good. The present results confirm the conclusion of previous experiments both as to the existence of the effect and as to its approximate magnitude.

* P. Kusch and H. M. Foley, Phys. Rev. **74**, 250 (1948).

A10. Amplitude Bridge for Nuclear Resonance Detection. R. D. HUNTOON AND H. A. THOMAS.—An amplitude bridge, sensitive only to the absorption component of nuclear magnetic resonance, offers advantages in applications where simplicity, ease of adjustment, and freedom from microphonics are more important than minimum noise figure. The voltages in two branches of an r-f network, one containing the sample, are rectified by diode detectors whose rectified outputs are balanced against each other to suppress oscillator noise and hum. The absorption signal is amplified to useful level by a simple audio amplifier. As expected, the noise figure is high, but peak signal to r.m.s. noise ratios of over 100 have been attained. The most striking feature is the freedom from microphonics. Performance data and noise figures for crystal diodes and high vacuum diodes will be presented.

A11. Nuclear Gyromagnetic Ratios. JOHN R. ZIMMERMAN AND DUDLEY WILLIAMS, *Ohio State University.*—By a method involving super-regenerative oscillators we have observed magnetic resonance absorption by seventeen nuclear species. The absorption frequencies of various nuclei have been measured in a magnetic field in which the proton frequency was measured simultaneously. Results for twelve nuclei are listed in the accompanying table.

Nucleus	Ratio of resonance frequency to proton frequency in same magnetic field
H^3	0.15355 ±0.03%
Li^7	0.38865 ±0.01%
B^{11}	0.32074 ±0.03%
F^{19}	0.94086 ±0.02%
Na^{23}	0.26454 ±0.03%
Al^{27}	0.26064 ±0.04%
Cu^{63}	0.26515 ±0.02%
Cu^{65}	0.28404 ±0.03%
Br^{79}	0.25059 ±0.02%
Br^{81}	0.27014 ±0.02%
Rb^{87}	0.32718 ±0.05%
I^{127}	0.20003 ±0.03%

Invited Paper

A12. Progress in the Study of Nuclear Magnetic Resonance Since the 1948 Symposium at Washington. E. M. PURCELL, *Harvard University.* (40 min.)

THURSDAY MORNING AT 10:00

Departmental Auditorium

(J. C. STREET presiding)

Cosmic Rays

B1. Laboratory Coincidence, Anti-Coincidence Unit. C. A. SCHROEDER, J. D. SHIPMAN, JR., AND P. R. MCCRAY, *Naval Research Laboratory.*—A laboratory unit for detection and recording of coincidence and anti-coincidence events from counter tubes has been developed. The unit employs diode coincidence circuits[1] which are so arranged that by use of a switch board the electronic circuits for most counter experiments can be set up in a short time. Six sets of input leads are available, each of which may be connected to a counter. Six output channels furnish to recorders as many independent sets of data. Any desired six of a great variety of coincidence and anti-coincidence events may be recorded. The coincidence resolving time is approximately 5 microseconds.

[1] Howland, Schroeder, and Shipman, Rev. Sci. Inst. 18, 551 (1947).

B2. A Test Set for Measurement of Dead Time and Recovery Time of Counters. K. SITTE, *Syracuse University.*—A simple laboratory test set is described which permits a quick determination of dead time and recovery time of counters. The counter pulse, after passing a preamplifier, is fed into a mechanical recorder through a discriminator. This part of the arrangement can be set to record pulses of varying minimum size. For the actual measurements, the recorder is biassed off except for a variable short time after each pulse. This is done by a multivibrator of the Maier-Leibniz type.[1] Only pulses following the first within this short interval are thus registered, and by making the discriminator pass full-sized pulses only, or smaller pulses, the time required for full or partial recovery is quickly determined. This method has been found very convenient for routine counter tests. Some applications, especially to aged counters, will be described.

[1] Maier-Leibniz, Rev. Sci. Inst. 19, 500 (1948).

B3. Search for Systematic Variations in Cosmic-Ray Intensity Predicted on the Basis of a Permanent Solar Magnetic Moment. S. E. FORBUSH AND I. LANGE, *Carnegie Institution of Washington.*—M. S. Vallarta and O. Godart pointed out [Rev. Modern Phys. 11, 180 (1939)] that certain small periodic variations in cosmic-ray intensity would be expected if the sun has the permanent magnetic moment of 10^{34} gauss-cm^3 which would explain the knee of the latitude effect. They pointed out that if the solar moment is sufficiently inclined to the sun's axis of rotation, then the solar cut-off energy would vary with a period of about 27 days, leading to a periodic 27-day variation in intensity. From the inclination of the sun's axis of rotation to the ecliptic, Vallarta and Godart estimated that a variation in intensity with period of six months would be expected whether or not the rotational and magnetic axes of the sun coincide. Data from several Compton-Bennett ionization chambers obtained over a period of ten years or more have been subjected to statistical analysis to determine whether there is evidence for the existence of such periodic variations. The principal 27-day variation is found to be the quasi-periodic 27-day recurrence tendency well known in terrestrial magnetic activity. The amplitude of the periodic 27-day variation is only about 0.1 percent and this is found too small to be regarded as statistically significant. The six-month variation derived from data at three stations was found to have an amplitude of about 0.1 percent with maxima in March and September; both the phase and amplitude agree well with the predictions of Vallarta and Godart.

B4. Correlation of Cosmic-Ray Geomagnetic Effects.* H. V. NEHER, *California Institute of Technology.*—In a B-29 flight at 30,000 feet (3.10 m of water equivalent) to Peru and return, the intensity of cosmic rays at 45° toward the east and the west as well as at the vertical was measured continuously with counter telescopes from geomagnetic latitude 64° north to the equator. These measurements were made with no lead, 10 cm and 20 cm lead absorber. In addition the variation in azimuth at 38,000 ft. over Peru (2.35 m of water equivalent) was also measured for zenith angles of 22½°, 45°, and 67½°. An attempt is made to correlate the calculations of Vallarta and others on the behavior of charged particles in the magnetic field of the earth with the measured latitude effect, azimuthal effect, and east-west effect. It is concluded that under the assumption of only one kind of incident, positively charged primary particle that the theoretical calculations and the experimental results are in agreement.

* This work was supported in part by the joint program of the ONR and AEC.

B5. A Search for Cosmic-Ray Diurnal Effects at Rocket Altitudes. G. J. PERLOW, C. W. KISSINGER, AND C. A. SCHROEDER, *Naval Research Laboratory.*—An experiment was performed to investigate a possible diurnal effect in the cosmic radiation at rocket altitudes. Identical apparatus was carried in two rockets, one launched in daylight and one the following night. The apparatus consisted of a central vertical counter tube surrounded by a closely packed ring of vertical counters, the latter being connected in parallel. Coincidences between the outer ring and the central counter determined the intensity of ionizing rays, while anti-coincidences gave the intensity of γ-radiation in the energy range 0.08–5 Mev approximately. The apparatus accepted radiation from all directions, above and below. The curve of ionizing radiation *versus* altitude showed the usual shape with a maximum at 20 km and was the same for day and night. The γ-radiation increased to a maximum at a slightly lesser altitude, and dropped off to a plateau with increasing altitude. No significant difference was observed between night and day. Some, if not all, of the γ-ray plateau is to be attributed to diffusion back from the atmosphere. In a copper-walled counter of 0.9-mm wall thickness the soft γ-ray counting rate above the atmosphere is 7 percent of the counting rate due to all radiation.

B6. Gamma-Rays in the Primary Cosmic Radiation. C. W. KISSINGER, C. A. SCHROEDER, AND G. J. PERLOW, *Naval Research Laboratory.*—In the daytime rocket of the previous abstract, a counter telescope was installed to measure the vertical γ-ray intensity in a higher energy range. Two thin-wall counters in coincidence counted electrons of sufficient energy to penetrate a copper absorber 1.6 mm thick placed between them. The electrons were formed by γ-ray conversions in a semi-cylindrical lead annulus 6.3 mm thick placed above the counters. Ionizing radiation was excluded by requiring anti-coincidence with a tight row of counters covering the annulus. The highest energy measurable was limited by 2.3 cm of lead below the twofold set and a row of anticoincidence counters below this. The instrument was sensitive to γ-rays in the energy range 2.5–70 Mev approximately. The γ-ray counting rate was determined as a function of altitude. Ionizing rays through the twofold telescope were registered for comparison. The γ-ray

intensity reached the expected maximum and diminished to a plateau at greater altitude. At 60 km, the ratio of non-ionizing to ionizing vertical counting rates was 6 percent before application of corrections for instrumental effects. The corresponding ratio on the ground was 12 percent.

B7. Further Results in the Search for Electrons in the Primary Cosmic Radiation.* ROBERT I. HULSIZER, *Massachusetts Institute of Technology.*—The experimental results reported last June have been substantiated by further measurements which were extended to include bursts (under 2.5 cm of lead) corresponding to 30 high energy electrons traversing the chamber as opposed to 80 for the earlier measurements. This change was made because the energy assigned to the incident electron responsible for the larger bursts should have been 10^{10} ev rather than 4×10^{9} ev. With a brass chamber wall 0.6 g cm^{-2} thick, an electron of 5×10^{9} ev incident on the lead would cause 30 electrons to traverse the chamber. The rate of bursts of this size observed at an atmospheric depth of 27 g cm^{-2} was 4580 ± 100 hr.$^{-1}$. A directional intensity of 0.0082 particles cm^{-2} sec.$^{-1}$ sterad^{-1} is estimated from this rate for the burst producing radiation. As much as 15 percent of the bursts are due to stars rather than electron showers, while preliminary measurements indicate that some of the bursts due to electron showers are not caused by electrons incident on the lead, but by electrons produced in the lead by a more penetrating radiation.

* This work was supported by the joint program of the ONR and the AEC.

B8. Momentum Spectra and Positive Excess of Cosmic Ray Particles at 11,000 Feet.* CHARLES E. MILLER, JOSEPH E. HENDERSON, D. S. POTTER, JAY TODD, JR., AND A. W. WOTRING, *University of Washington.*—About 18,000 counter controlled cloud-chamber photographs have been obtained at Climax, Colorado (elevation 11,200 ft.). Field strengths of 8200 and 10,000 gauss were used with a chamber diameter of 17 cm. Data were taken with no absorber and with five and twenty cm of lead above the chamber. Curvatures of all singly occurring and apparently counter controlled tracks of length at least 85 percent of the chamber diameter are being measured first. Measurements have been completed for approximately one-fourth of the total data. This incomplete, but still fairly extensive information, shows for the no absorber case a momentum distribution that rises sharply below 350 Mev/c and has maxima at 500 and 900 Mev/c, while those tracks obtained under five cm of lead show a rapid decrease in numbers below 350 and a maximum at 900 Mev/c. Tracks under five cm of lead show a positive excess of 1.6 in the range from 0 to 2000 Mev/c. Preliminary examination of the entire data shows that about 2 percent of the tracks correspond to more than minimum ionization and have curvatures commensurate with protons.

* Supported by the Bureau of Ordnance, Navy Department.

B9. On the Neutrons in the Atmosphere.* J. A. SIMPSON, JR., H. W. BALDWIN, AND R. B. URETZ, *University of Chicago.*—Measurements of the slow neutron density in the atmosphere have been made at 30,000 feet pressure altitude in a B-29 aircraft tail section free from materials of high atomic number and, therefore, corresponding to free-space measurements. The slow neutron density has the same latitude dependence as that found earlier for the fast neutrons (for example, a 2.5 fold increase in intensity between the magnetic equator and 40° north magnetic latitude at 30,000 feet). Using enriched BF_3 proportional counters, the ratio of neutron densities between an unshielded and a cadmium shielded counter was approximately 2.0 to 2.1 at the magnetic equator and at 40° north magnetic latitude in agreement with earlier measurements at the higher latitudes. Preliminary measurements have been made of the shape of the neutron density latitude curves in the region of 40° to 62° north magnetic latitude at a few altitudes in winter and summer. It appears that the neutron density at 54° north magnetic latitude in summer is greater than or equal to the same measurement made in winter, and that a well defined bend or "knee" exists with a maximum curvature at approximately 50° north magnetic latitude for 30,000 feet altitude.

* This work was supported in part by the ONR.

B10. Distribution of Slow Neutrons in Free Atmosphere up to 102,000 Feet.* LUKE C. L. YUAN, *Princeton University.*—The measurements of slow neutrons in the free atmosphere as reported up to an altitude of 67,000 feet[1] have been extended to 102,000 feet. The same exponential increase of slow neutrons with altitude and the same maximum at about 8.5 cm pressure as before was obtained, but the number of counts were more than 2 times as large corresponding to higher density of enriched boron in the counters. Passing the maximum, the slow neutron intensity drops sharply and reaches at 0.75 cm pressure nearly one-fourth of its maximum value. By determining the counter efficiency, the absolute value of the slow neutron intensity has been determined. The absolute value of the slow neutron production rate in the atmosphere, based on the neutron intensity obtained, will be compared with the rate of production of protons from stars in the atmosphere.

* Assisted by the joint program of the AEC and the ONR.
[1] L. C. L. Yuan, Phys. Rev. **74**, 504 (1948).

B11. The Properties of Cosmic Radiation in the Lower Atmosphere.* MARTIN A. POMERANTZ, *Bartol Research Foundation.*—Experiments performed previously with apparatus carried to very high altitudes by free balloons have been conducted in the lower portion of the atmosphere. Two different instruments were operated in a B-29 airplane, and at Mt. Evans, Colorado. Absorption curves in lead, up to a thickness of 18 cm, were obtained at 14,260 feet, 25,000 feet, and 30,000 feet. Intensity *vs.* altitude curves for the lower regions of the atmosphere may now be combined with those for very high altitudes without an arbitrary normalization. A direct comparison has been made between the present measurements and those of others regarding the relative change of intensity between sea level and Mt. Evans, and the absorption in lead at Mt. Evans. Factors for the conversion of all of the data to absolute intensities have been determined utilizing a γ-ray howitzer method for measuring the effective length of a G-M counter. Satisfactory agreement is noted between values of the absolute intensity previously measured by others at sea level and at Mt. Evans, and those reported herewith. The absolute intensity of cosmic-ray particles near the "top of the atmosphere" at geomagnetic latitude 53°N is given as 10.1 ± 0.20 particles/min./cm^2/unit solid angle.

* This work was assisted by the joint program of the ONR and the AEC.

B12. Soft X-Radiation in the Upper Atmosphere. T. R. BURNIGHT, *Naval Research Laboratory.*—A simple experiment consisting of small casettes containing photographic films and plates behind thin aluminum and beryllium windows of various thicknesses have been flown in a number of rockets at White Sands. On August 5, 1948 such an experiment obtained exposures through .076 cm beryllium windows indicating an unexpected intensity of radiation of wave-length shorter than 4 angstroms. On November 18, 1948 an experiment with .00076 and .00153 cm thickness aluminum and .0254 cm beryllium windows was flown with no indication of x-rays being obtained. On December 9, 1948 an identical experiment obtained appreciable blackening through .00076 cm aluminum windows but not through .0254 cm beryllium windows. The sun is assumed to be the source of this radiation although radiation of wave-length shorter than 4 angstroms would not be expected

from theoretical estimates of black body radiation from the solar corona. A semiquantitative determination of the intensities indicated has been made, and the possible correlation with solar activity at the time of firing will be presented.

B13. Observations at High Altitudes of Extreme Ultraviolet and X-Rays from the Sun. J. D. PURCELL, R. TOUSEY, AND K. WATANABE.—A phosphor of $CaSO_4$ and $MnSO_4$ was shown by Lyman[1] to be thermoluminescent after exposure to extreme ultraviolet radiation of wave-lengths shorter than 1300A. This sensitivity has now been found to extend also to x-rays. Samples of this phosphor were carried in V-2 rockets on November 18, 1948 and February 17, 1949 to altitudes of 90 and 79 miles. They were exposed to radiation from the sun for approximately 3 minutes. Some were bare and some were covered with filters of CaF_2, LiF, and beryllium. After recovery the several phosphor strips were heated and the thermoluminescence measured by means of a photomultiplier. A positive result was obtained in each case. Approximately $\frac{1}{16}$, $\frac{1}{3}$, and $\frac{1}{2}$ of the thermoluminescence observed for the phosphor without a filter was recorded for the phosphors covered with the Be, CaF_2, and LiF filters, respectively. This is considered to be a direct observation of the presence at high altitudes of a considerable intensity of solar radiation in wave-length regions between 1300 and 1230, 1230 and 1100, and below 1100A. The positive indication through Be can be explained only by the presence of x-rays.

[1] T. Lyman, Phys. Rev. **48**, 149 (1935).

THURSDAY MORNING AT 10:00

East Building, National Bureau of Standards

(F. G. BRICKWEDDE presiding)

Heat and Cold

C1. A Non-Linear Problem in Transient Heat Flow. BRUCE L. HICKS, *Ballistic Research Laboratories.*—In a simple theory of thermal ignition of a solid one requires a solution $u(\xi, \tau)$ of the system $u_\tau = u_{\xi\xi} + \exp(-1/u)$; $-u_\xi/\xi = 0 = H[u_g - u(0, \tau)]$ >0; $u(\xi, 0) = u^{(0)}$; $u_\xi \to 0$, $\xi \to \infty$; $\xi \geqslant 0$, $\tau > 0$. The parameters $u^{(0)}$, H, and u_g correspond to initial temperature, heat transfer coefficient, and gas temperature. Of special interest is the time τig required for the surface temperature $u(0, \tau)$, under the influence of internal heat sources $\exp(-1/u)$ and of external heating from the gas, to rise to the value 0.05, measured in units of (E/R). Numerical integrations have been performed in the Ballistic Research Laboratories' Computing Laboratory for various combinations of the three parameters. Since the calculations were time consuming (about 3×10^4 net points used in computations with desk machines and the Bell Relay Computer), an approximate analytical derivation of the dependence of τig upon $u^{(0)}$, H, and u_g was developed. Thus a function $v(\xi, \tau)$ was found which satisfied the system with the exponential term omitted. The value of τig was then determined from the implicit equation $\exp[-1/v(0, \tau ig)]$ $= \alpha v_{\xi\xi}(0, \tau ig)$ for several values of each of the three parameters. When $\alpha = 4.0$ the values of τig computed in this way differ by less than 20 percent from the values obtained by numerical integration even though τig varies from 10^8 to 10^{17}.

C2. Large Diameter "Hilsch Tubes." LESTER I. BOCKSTAHLER AND HARMON PLUMB, *Northwestern University.*—preparatory to using the "Hilsch tube" as a "heat separator" at high pressures (150 atmos.), an experimental study was made of models several times larger than those reported by Hilsch[1] and by Johnson.[2] Particular attention was given to designs favoring the initiation of the centrifugal or vortex motion of the entering gas. Eccentric deflector rings with varying number of turns and different pitch were used to direct the spiral flow. The maximum cooling for most favorable disposition and size of nozzle, diaphragm, and flow rates was 38°C. This compares favorably with values reported for smaller tubes.

[1] R. Hilsch, Z. Naturforsch. **1**, 208 (1946); R. Hilsch, Rev. Sci. Inst. **18**, 108 (1947).
[2] Johnson, Can. J. Research **25**, Section F, 299 (1947).

C3. The Temperature Variation of the Thermal Diffusion Constant of HCl. GWYNNE B. SWARTZ, *Yale University.**—"Two-bulb" thermal diffusion experiments have been performed in which a variation in the thermal diffusion constant for HCl gas has been observed over a range of temperature T_τ from 240°K to 560°K. The results show a "softening" of the HCl molecule as the temperature decreases, and also a reversal in the sign of α at about 485°K. The variation in α is linear with respect to the logarithm of T_τ to within the limits of experimental error. The overall agreement with the Lennard-Jones 9,5 model is quite good; in particular the reversal point of 485°K is very nearly equal to 1.54 times the critical temperature, 324°K, as predicted by the 9,5 model.

* Now at University of Maryland.

C4. Emittances of Copper and Aluminum Spheres. GEORGE BEST (Introduced by Lester I. Bockstahler), *Northwestern University.*—The total hemispherical emittances of copper and aluminum spheres were determined over the range of temperatures from 100°C to 400°C. The spheres were heated electrically from within and were placed concentrically in an evacuated spherical flask which was kept at constant temperature by the circulation of ice water over its outer surface. The specimens had a diameter of 4.5 cm and the flask a diameter of 28 cm. Temperatures of the spheres were measured on the inner surfaces with copper-constantan thermocouples; since the wall thickness was of the order of 0.3 mm, the inner and outer surface temperatures were assumed the same. Heat losses through the thermocouple and power leads were evaluated by a substitution method. Polishing was done mechanically using a modified metallographic procedure with levigated alumina. The results were reproduceable over the range of temperatures but varied somewhat from published values obtained by other methods.

C5. The Transformation Theory of Thermodynamics. H. C. CORBEN, *Carnegie Institute of Technology.*—For a one component reversible system acted upon by hydrostatic forces, the first two laws of thermodynamics may be regarded as prescribing a contact transformation from the PV plane to the TS plane generated by the internal energy U, the pressure and temperature playing the roles of momenta conjugate to the volume and entropy, respectively. Alternatively, the enthalpy and Helmholtz and Gibbs free energies may be regarded as generators of this transformation. With a periodic process we

may associate an action integral $J = \oint PdV$, although the work done in a non-periodic reversible change appears as a quasi-coordinate. The analogy with mechanics may be extended by introducing Poisson bracket expressions, which are invariant under the transformation, and in terms of which observable thermodynamical variables may be expressed. The theory leads to a systematic method of listing the many partial differential equations of thermodynamics which is essentially equivalent to the Jacobian method of Shaw.[1] Lagrangian and Hamiltonian formalisms may be developed, and the method may be extended to many-component systems under generalized stresses, where the masses of the various components become additional coordinates to which the chemical potentials are conjugate momenta.

[1] A. N. Shaw, Phil. Trans. Roy. Soc. **A234**, 299 (1935).

C6. Thermodynamics: The Meaning of the First Law, and Its Relation to the Behavior of Material Systems. J. L. FINCK, *The J. L. Finck Laboratories.*—In previous papers the writer developed the concept of a complete system. Such a system is defined by n independent variables, where n is the minimum number required to define all the properties of the system completely. In this paper he shows that the equation $E=\phi(\alpha_1, \cdots, \alpha_n)$, where E is the energy of the system, is equivalent to the statement of the first law in its broadest sense. It is shown that systems which are treated mathematically by a set of Hamiltonian equations are actually incomplete systems, and they are but special cases of the most general system covered by the above equation. For a complete system it is shown that friction, viscosity, electric resistance, magnetic reluctance, and thermal conductivity will all vanish. The thermodynamics of compressible fluids, mechanically oscillating systems, and chemical systems are considered from the standpoints of the system being complete and incomplete. Also, equilibrium and stability are considered from the same standpoint. The anomalous properties of matter at temperatures near absolute zero are readily explained, from a macroscopic standpoint, on the basis of a complete system. Phenomena such as superconductivity of metals, specific heat, thermal conductivity, and viscosity, the fountain effect and Rollin film for liquid helium II are explained.

C7. Experiment with Alternating Currents on Tin Superconductors.* B. SERIN, J. R. FELDMEIER,** AND M. GARFUNKEL, *Rutgers University.*—The technique[1,2] of superimposing direct and alternating currents on a superconductor and measuring the d.c. potential difference as a function of the amplitude of the alternating current has been used with tin wires. The samples, in the form of straight wires about 8 cm long and 10^{-2} cm in diameter were made by drawing tin (99.993 percent purity) in glass, and then removing the glass with HF; the samples were polycrystalline. Tin current and potential leads were welded to the wires. It was observed that as the amplitude of the a.c. current was increased, the d.c. potential difference increased, went through a maximum, and finally approached an asymptotic value, in agreement with the previously reported results for thallium.[1] At 50 cycles/sec., the experimental curves agreed with those calculated from the measured d.c. quenching current curve. As the frequency was increased up to 20 kc/sec., the curves shifted to higher current values and the value of the maxima increased. Similar results have been obtained with mercury samples.

* This work was supported by the Rutgers University Research Fund and by the joint program of the ONR and the AEC.
** Now at College of St. Thomas, St. Paul, Minnesota.
[1] B. G. Lasarev, A. A. Gelkin, and V. I. Khotkevich, J. Phys. U.S.S.R. **4**, 380 (1941); Comptes Rendus U.R.S.S. **55**, (No. 9), 805 (1947).
[2] See also: F. B. Silsbee, F. G. Brickwedde, and R. B. Scott, J. Research Nat. Bur. of Stand. **20**, 109 (1938).

C8. Surface Resistance of Superconducting Tin at 9400 mc/sec.* WILLIAM M. FAIRBANK,** *Yale University.*—The surface resistance of white tin has been determined at a frequency of 9400 mc/sec. between 75°K and 1.26°K. Johnson Matthey tin was formed by a die into a rectangular cavity operating in the TE_{011} mode. The unloaded Q was found to change from 6×10^3 at 75°K to 2.3×10^4 at 3.72°K to 1.2×10^6 at 1.26°K. In the non-superconducting region, in agreement with other workers,[1] the a.c. resistance becomes independent of the d.c. resistance. In this region the experimental curves are compared with the theoretical curves.[2] In the region below the superconducting transition temperature, the resistance falls to about 2 percent of its value at the transition temperature, a residual resistance apparently remaining at absolute zero. This data is compared with the data of Pippard[3] and the probable dependence of this residual resistance on the method of preparing the tin samples is discussed.

* Assisted by the ONR.
** Now at Amherst College.
[1] H. London, Proc. Roy. Soc. **A176**, 522 (1940); A. B. Pippard, Proc. Roy. Soc. **A191**, 371 (1947); E. Maxwell, P. M. Marcus, and J. C. Slater, Phys. Rev. **74**, 1234 (1948).
[2] G. E. H. Reuter, and E. H. Sondheimer, Proc. Roy. Soc. **A195**, 336 (1949).
[3] A. B. Pippard, Nature **162**, 68 (1948).

C9. Time Effects in Superconducting Cylinders. ROBERT T. WEBBER, *Yale University.**—The existence of long time delays between the sudden change of applied magnetic field and the reaching of a final value of induction in a superconducting specimen was first observed by Mendelssohn and Pontius.[1] We have studied the nature of these time effects for magnetic fields transverse to three types of spectroscopically pure tin cylinders: (1) solid and single crystal, (2) polycrystalline and hollow with open ends, and (3) polycrystalline and hollow with closed ends. All three specimens had outside dimensions of approximately 8 mm diameter and 10 cm length. The induction in the cylinders (determined by a small bismuth field probe) and the applied magnetic field were continuously recorded. All three specimens showed time effects in the intermediate state. Those in the solid cylinder were small and approximately exponential. In the hollow cylinders, several time effect patterns were observed depending on the original state of the specimen and the magnitude of the change of applied field. These time effects exhibited two distinct parts: a period of up to 40 seconds where no measurable change of induction occurred, followed by a long period, approximately exponential decay toward equilibrium.

* This work was assisted by the ONR.
[1] K. Mendelssohn and R. B. Pontius, Nature **138**, 29 (1936).

C10. Magnetic Susceptibility Measurements at Liquid Helium Temperatures. T. R. MCGUIRE, *Yale University.**—A modified Hutchison-Reekie[1] balance has been constructed to make magnetic susceptibility measurements on metallic single crystals in the liquid helium temperature range. The measurements were made by the Faraday body-force method wherein the specimen is placed in an inhomogeneous magnetic field H. The force F on the specimen of volume V is then given by

$$\mathbf{F}=((K-K_0)/2)V\nabla\mathbf{H}^2,$$

where K and K_0 are, respectively, the magnetic susceptibilities per unit volume of the specimen and surrounding medium. The following metals of known purity were obtained in single crystal form: aluminum, magnesium, mercury, thallium, and tin. The susceptibility was measured at room, liquid nitrogen, and liquid helium temperatures down to 1.6°K. Changes in susceptibility from 5 to 20 percent as a function of temperature were found. There was no evidence of the deHaas-van Alphen effect which is a field dependence of magnetic susceptibility.

* Assisted by the ONR.
[1] T. S. Hutchison and James Reekie, J. Sci. Inst. **23**, 209 (1946).

C11. Heat Flux Separation of He^3 in Liquid Helium II. C. A. REYNOLDS, H. A. FAIRBANK, AND C. T. LANE, *Yale Uni-*

*versity** AND B. B. MCINTEER AND A. O. C. NIER, *University of Minnesota.***—Helium has been enriched in the He^3 isotope to concentrations as high as 4 percent by a heat flux method similar to that reported previously.[1] The new apparatus, of improved geometry, consists of a 2 cc Pyrex bulb surrounded by a vacuum jacket and is connected at the top through a glass capillary to a Kovar section. A heater coil is in the bottom of the bulb. The Kovar is connected to a filling and sampling line. The whole apparatus is surrounded by a liquid helium II bath, the level of which is always above the bottom of the Kovar. Helium gas, enriched in the He^3 isotope to a concentration of 10^{-4} by thermal diffusion, is condensed in the bulb. The amount of gas put in is fixed so that the level is in the Kovar section. Heat from the coil can pass only up through the enriched liquid helium to the Kovar section and out into the bath because of the vacuum jacket. Samples have been taken with a fixed heat input at various temperatures and also at a fixed temperature (1.8°K) with different heat input.

* Assisted by the ONR.
** Assisted by the Joint Program of the ONR and the AEC.
[1] C. T. Lane, H. A. Fairbank, L. T. Aldrich, and A. O. C. Nier, Phys. Rev. **73**, 256–257 (1948).

THURSDAY MORNING AT 10:15

Department of Interior Auditorium

(F. W. LOOMIS presiding)

Symposium on Spectroscopy and Molecular Structure

E1. Where We Stand with Respect to Atomic Spectra. W. F. MEGGERS, *National Bureau of Standards.* (30 min.)

E2. Where We Stand in Respect to Spectra of Diatomic Molecules. G. HERZBERG, *National Research Council (Canada).* (30 min.)

E3. Where We Stand in Respect to the Electronic Structure of Molecules. R. S. MULLIKEN, *University of Chicago.* (30 min.)

E4. Where We Stand in Respect to Radiofrequency Studies of Molecular Structure. C. H. TOWNES, *Columbia University.* (30 min.)

THURSDAY AFTERNOON AT 2:00

Department of Interior Auditorium

(R. S. MULLIKEN presiding)

Conclusion of the Symposium on Spectroscopy and Molecular Structure

F1. Spectra and Structure of Borohydrides and Related Compounds. H. C. LONGUET-HIGGINS, *University of Chicago.* (30 min.)

F2. The Vibrational Spectrum of the Ethylene Molecule. B. L. CRAWFORD, *University of Minnesota.* (20 min.)

F3. Selection Rules for Infra-Red and Raman Spectra of Molecular Crystals. D. F. HORNIG, *Brown University.* (30 min.)

F4. Some Recent Results on Molecular Structure Obtained by Means of the Raman Effect. D. H. RANK, *Pennsylvania State College.* (30 min.)

F5. Fluorescence and Phosphorescence Spectra of Organic Molecules. MICHAEL KASHA, *University of California* (Berkeley). (30 min.)

THURSDAY AFTERNOON AT 2:15

Department of Commerce

(A. M. WEINBERG presiding)

Reactions of Transmutation

G1. Angular Distribution of Protons from the $D-D$ Reaction for 10-Mev Deuterons. H. A. LEITER, R. E. MEAGHER, F. A. RODGERS,* AND P. GERALD KRUGER, *University of Illinois.***—The angular distribution of the protons produced by the bombardment of deuterons by 10-Mev deuterons has been measured at 10° intervals from 15° to 65° in the laboratory system. Photographic plates were used as detectors in a gas-filled scattering chamber. The H^3, He^3, and elastically

scattered H^3 were stopped by an aluminum foil covering the photographic plates. The track background due to the neutrons from the $D-D$ and other D, n reactions was determined by performing a check experiment under conditions such that no disintegration protons could reach the photographic plates. The measured absolute differential cross sections at angles 21° 23′, 28° 26′, 35° 27′, 42° 24′, 49° 15′, 56° 1′, 62° 40′, 69° 12′, 75° 36′, 81° 50′, and 87° 54′ in the center of mass system are 1.62, 0.97, 0.45, 0.27, 0.26, 0.33, 0.40, 0.46, 0.46, 0.46, 0.45 $\times 10^{-26}$ cm², respectively.

* Now at University of Wisconsin.
** Supported jointly by ONR and AEC.

G2. Differential Cross Sections for the Reaction $T^3(p, n)He^3$ from 1 to 2.5-Mev Proton Energies. G. A. JARVIS, A. HEMMENDINGER, H. V. ARGO, AND R. F. TASCHEK, *Los Alamos.*—The angular distributions of neutrons from the $T^3(p, n)He^3$ reaction have been measured in 200-kev steps from the threshold at 1.019-Mev proton energy up to 2.5 Mev. The distributions in the center of mass system were fitted with cosine series and integrated to obtain total cross sections. It is necessary to include cosine-cubed terms to fit the data at higher energies. The total cross section rises to 0.55 barn at 2.4-Mev proton energy and is still rising at a fairly rapid rate at this energy.

G3. Use of Photographic Plate Detectors in Experiments with 10-Mev Deuterons. J. H. WILLIAMS, F. K. TALLMADGE, L. ROSEN, *Los Alamos.*—Photographic plates are being successfully utilized to make energy distribution and intensity measurements of the products of reactions induced by the externally focused 10-Mev deuteron beam from the Los Alamos cyclotron. Results of a search for an excited state in the H^3 nucleus will be given. Preliminary results will also be given for $D-P$ scattering. A camera now under construction, which will be capable of simultaneously recording intensity and energy distribution of the charged products of nuclear disintegrations and scatterings in 2.5-degree intervals from 10 degrees to 170 degrees with respect to the incident deuteron beam, will be briefly discussed.

G4. Angular Correlations in Successive $\alpha-\gamma$ Emission and the Excited State of Li^7.* BERNARD T. FELD, *Massachusetts Institute of Technology.*—The 480-kev excited state of Li^7 has been observed in a variety of nuclear reactions. Measurements of the excitation energy are in fair agreement, but do not exclude the possibility that the excited state is a closely spaced doublet, as suggested by Inglis.[1] The following experiment can provide information concerning the Li^{7*} state. In the reaction $B^{10}(n, \alpha)Li^{7*}(\gamma)Li^7$, the coincidence $\alpha-\gamma$ angular correlation depends on the states involved. If the Li^{7*} state is $^2P_{1/2}$, there can be no angular correlation. On the Inglis suggestion of a $^2F_{5/2, 7/2}$ intermediate state, assuming the emitted α-particle has $L=1$, the angular correlation function is $W(\theta)=1+Q\cos^2\theta$. Q has been computed for all possible combinations of initial B^{11} (spin 5/2 or 7/2), intermediate Li^{7*} (5/2, 7/2), and final Li^7 (1/2, 3/2) states. For most possibilities Q is large. Positive angular correlation would exclude the $^2P_{1/2}$ possibility. An experiment is under way, in this laboratory, to measure $W(\theta)$.

* Supported, in part, by the joint program of the ONR and the AEC.
[1] D. R. Inglis, Phys. Rev. **74**, 1876 (1948).

G5. Lifetime of the 479-Kev Excited State of Li^7. L. G. ELLIOTT AND R. E. BELL, *Chalk River Laboratories.*—The measurement of an upper limit for the lifetime of the 479-kev excited state of Li^7 reported previously[1] has been extended to give a definite value for this lifetime. The source was the reaction $B^{10}(n, \alpha)Li^{7*}$ taking place in a beam of thermal neutrons from the pile. Photoelectron lines ejected from a thin U-shaped radiator by the Li^{7*} γ-rays and by 470-kev Ir^{192} (70 day) γ-rays were compared in a lens-type β-ray spectrometer. The recoil velocity of the Li^{7*} atoms causes a Doppler spread of 3.22 percent in their γ-ray energies, provided that the γ-rays are emitted before the Li^{7*} atoms are slowed down by the source material. The width of the photoelectron line in the spectrometer was seen to increase as the slowing-down time of the Li^{7*} atoms was increased by using FeB, B_4C, and $LiBH_4$, respectively, as target materials. From this comparison of the Li^{7*} lifetime with the known slowing-down times we get a lifetime $\tau=(0.75\pm0.25)\times10^{-13}$ sec., in fair agreement with calculations[1] based on existing models of the Li^7 nucleus.

[1] L. G. Elliott and R. E. Bell, Phys. Rev. **74**, 1869 (1948).

G6. The Gamma-Ray Resonance at 440 Kev in Li^7 Plus Protons. ERIC RIDGEWAY, *Philadelphia.* (Introduced by J. Smith.)—The present controversy[1,2] regarding the exact position of the 440-kev resonance in the gamma-ray yield of Li^7 plus protons makes timely an evaluation of the problem in terms of physico-musical constants. By analogies and symmetry arguments it will be shown that the resonance must occur at precisely 440 kev, in agreement with 440 c.p.s., standard pitch of A_3 on the equal tempered chromatic scale. The persistent recurrence of the pure number 440, believed to be deep-seated in nature, will be discussed in terms of Planck's constant, the fine structure constant, and the velocity of light.

[1] A. O. Hanson and D. L. Benedict, Phys. Rev. **65**, 33 (1944).
[2] Tangen, Kgl. Norske. Vid. Sels. Skrifter (1946) NRI.

G7. Angular Yield of Protons, Tritons, and Alphas from the Bombardment of Be^9 by Deuterons. I. RESNICK AND S. S. HANNA, *The Johns Hopkins University.*—The deuteron beam of the Physics Department statitron was used to bombard a thin Be^9 foil, mounted in a large semi-circular target chamber, previously used by J. A. Neuendorffer. Seven Ilford plates were arranged inside the chamber at positions 25° apart, and 22 cm from the target. The product particles passed through gaps in a semi-circular ring of iron, carrying a magnetic field. This reaction leads to a variety of product particles of which the following were recorded on the plates: two proton groups, two alpha-groups, and a single triton group. The magnetic deflection in the chamber separated the two proton groups and the triton group from each other. However, the alpha-groups were not resolved, and their deflection coincided with that of the long-range protons, but it was possible to distinguish them by means of track length. Plates taken at several voltages between 300 and 700 kev were counted, and angular distributions for the short-range protons, the long-range protons, the tritons, and both alpha-ranges together were obtained. Experiments are under way to determine the distributions of the separated alpha-groups by another method. The triton distribution shows a marked increase in intensity in the forward direction, the long-range protons exhibit a strong $\cos^2\theta$ dependence, while the short-range protons are roughly spherically symmetric.

G8. Excited State in Be^{10}. W. W. BUECHNER AND E. N. STRAIT, *Massachusetts Institute of Technology.*—The protons from $Be^9(d, p)Be^{10}$ have been analyzed magnetically. Two groups have been found corresponding to the formation of Be^{10} in the ground state and in an excited state of 3.36 Mev, the Q values being 4.58 and 1.22 Mev. This value for the energy level confirms that previously reported.[1] The resolution makes it possible to eliminate definitely the possibility that the low energy group is due to oxygen contamination. The groups from oxygen and beryllium were both found and differed in energy by 25 kev at the bombarding energy of 1 Mev employed. Preliminary observations have not shown the existence of a group attributable to an excited level of Be^{10} of energy less than 3.36 Mev. This abstract is based on work assisted by the joint program of ONR and AEC.

Lattes, Fowler, and Cuer, Proc. Phys. Soc., London **59**, 883 (1947).

G9. Bombardment of B^{10} with Deuterons.* CHARLES P. SWANN AND EMMETT L. HUDSPETH, *Bartol Research Foundation.*—The reaction $B^{10}(d, n)$ has been studied at a bombarding voltage of 1.4 Mev. The enriched (96 percent B^{10}) isotope was in elemental form, prepared from $B^{10}F_3 \cdot CaF_2$ obtained from Oak Ridge. Neutron groups of energies 1.2, 3.5, and 7.8 Mev were observed with photographic plates at 0°. The 7.8-Mev group ($Q = 6.6$ Mev) corresponds to the formation of C^{11} in the ground state. It was shown, as previously suspected, that the reaction $B^{11}(d, n)$ also yields a group of neutrons which, in bombardment of normal boron,[1] overlaps this group. The groups at 1.2 and 3.5 Mev may arise from $C^{12}(d, n)$ and $D(d, n)$ respectively, but intensity considerations indicate the contrary. We have also made a coincidence absorption study of Compton electrons produced by γ-rays from deuteron bombardment of normal boron and of B^{10}. It is found that most of the total radiation is produced by bombardment of B^{10}, but a γ-ray of energy 1.5 Mev (observed in bombardment of normal boron)[2] is associated with the bombardment of B^{11}; it probably arises from B^{12} decay. Further work on all of these reactions is in progress.

* Assisted by the Joint Program of ONR and AEC.
[1] T. W. Bonner and W. M. Brubaker, Phys. Rev. **50**, 308 (1936).
[2] Gaerttner, Fowler, and Lauritsen, Phys. Rev. **55**, 27 (1939); J. Halpern and H. R. Crane, Phys. Rev. **55**, 415 (1939).

G10. A Study of the Long Range Protons from the Bombardment of Carbon by Deuterons. G. C. PHILLIPS, T. W. BONNER, AND J. E. RICHARDSON, *Rice Institute.*—The cross section for the production of long range protons from the reaction ${}_6C^{12} + {}_1D^2 \rightarrow {}_7N^{14*} \rightarrow {}_7C^{13} + {}_1H^1 + 2.7$ Mev has been investigated. A thin target of 23.5 $\mu g/cm^2$ of pure carbon on a 7.75-mg/cm^2 silver foil was bombarded with deuterons in the energy range 0.80 to 1.50 Mev. The protons were counted with a proportional counter at 0°, 90°, and 150° to the beam. Resonances were observed at 0.91, 1.16, 1.30 Mev corresponding to known resonances for the competing reactions of neutrons and short-range protons. The narrow resonance at 1.435 Mev, previously shown only by the gamma-rays, also occurs for the long-range protons. A previously unidentified resonance of half-width ~20 kev was found at 1.14 Mev. The narrow resonance at 1.435 Mev has an unsymmetrical shape, and the energy at which the maximum occurs for different angles is shifted several thousand volts with respect to 1.435 Mev. The angular distributions for the 0.91- and the 1.16-Mev resonances are similar to the neutrons,[1] but are dissimilar at 1.30 Mev. There is an apparent anti-resonance for the 0° protons at 1.30 Mev.

[1] Bonner, Evans, Harris, and Phillips, in press.

G11. Highly Excited States of the Magnesium Nucleus Created by Proton Bombardment.* ROY BRITTEN, *Princeton University.*—Thin magnesium foils have been bombarded with 15.5-Mev protons in the Princeton f-m cyclotron. A thin and narrow, vertical foil of magnesium was placed inside the cyclotron so that it intercepted the circulating beam. The low energy inelastically scattered protons have been analyzed by two methods. In the first, nuclear plates wrapped in thin Al foil were placed in a horizontal plane around the scattering foil just below the plane of the beam. Thus the elastic and inelastic spectrum could be recorded at several angles. Track length distributions on these plates indicated that about 25 percent of the protons scattered in the backward direction have energies less than 4 Mev, corresponding to states more than 11 Mev above the ground state. In the second method, a 180° deflection camera was used to analyze protons between 1 and 4 Mev. The limit of resolution is set at about 0.1 Mev by the scattering foil thickness and the energy spread of the beam. The energy distribution was measured by a track count on plates placed along the line of focus. A fairly rapid increase in the number of protons per unit energy occurs from 4 Mev to a peak just below 2 Mev, in general agreement with the results from the first method.

* This work was assisted by the Joint Program of ONR and AEC.

G12. Q-Values for $Ca^{40}(d, p)Ca^{41}$ and the Mass Difference $(Ca^{40} - A^{40})$. VANCE L. SAILOR, *Yale University.**—Q-values for the reaction $Ca^{40}(d, p)Ca^{41}$ have been observed to be 6.17, 4.22, 3.76, 3.2, 2.9, 2.7, 2.5, 2.31 Mev. The value 6.17 Mev corresponds to formation of Ca^{41} in the ground state, giving the mass difference $(Ca^{41} - Ca^{40}) = 0.99997 \pm 0.00005\mu$. Also, the mass difference $(A^{41} - A^{40}) - (Ca^{41} - Ca^{40}) = 2.54 \pm 0.03$ mμ was obtained by placing both argon and calcium targets in the same bombardment chamber and comparing the ranges of the end groups of protons from the reactions $Ca^{40}(d, p)Ca^{41}$ and $A^{40}(d, p)A^{41}$. By using the additional values observed for $K^{41}(p, n)Ca^{41}$ threshold[1] and the A^{41} β^--decay energy,[2] the following mass difference was calculated:

$$(Ca^{40} - A^{40}) = [(A^{41} - A^{40}) - (Ca^{41} - Ca^{40})] - (Ca^{41} - K^{41}) - (A^{41} - K^{41}) = 0.27 \pm 0.21 \text{ m}\mu.$$

This is in good agreement with $Ca^{40} - A^{40}$ calculated from the decay scheme of K^{40} using 1.55 Mev for K-capture energy and 1.35 Mev for β^--energy, which gives $Ca^{40} - A^{40} = 0.22$ mμ.

* Assisted by the Joint Program of ONR and AEC.
[1] H. T. Richards and R. V. Smith, Phys. Rev. **74**, 1257 (1948).
[2] Bleuler, Bollman, and Zünte, Helv. Phys. Acta **19**, 419 (1946).

G13. The $Cu^{63}(n, 2n)Cu^{62}$ Cross Section as a Function of Neutron Energy near the Threshold. J. L. FOWLER AND J. M. SLYE, *Los Alamos.*—Using the $D(d, n)He^3$ reaction produced by 10-Mev deuterons to give neutrons, the $Cu^{63}(n, 2n)Cu^{62}$ reaction has been studied in the vicinity of the threshold. The energy of the bombarding deuterons is determined by magnetic deflection. This, together with the angle which the neutrons make with the beam, gives the neutron energy. The experiment consists of activating copper foils placed about a deuterium gas target which is bombarded by a monitored deuteron beam. The foils are then counted in cylindrical glass-walled Geiger counters. The product of the differential cross section of the $D(d, n)He^3$ reaction and the activation cross section of the $Cu^{63}(n, 2n)Cu^{62}$ reaction is obtained as a function of angle to the deuteron beam. By calibrating the Geiger counters with the beta-particles from Cu^{66} produced in a known flux of thermal neutrons, the data is made absolute in terms of the known thermal capture cross section of Cu^{65}. Previous measurements of the differential cross section of the $D(d, n)He^3$ [1] reaction allow the $Cu^{63}(n, 2n)Cu^{62}$ cross section to be given as a function of energy.

[1] Erickson, Fowler, and Stovall, Phys. Rev. **75**, 894 (1949).

THURSDAY AFTERNOON AT 2:15

Departmental Auditorium

(H. V. NEHER presiding)

Cosmic Rays, Mostly Penetrating Particles

H1. Uniformity of Response of a Scintillation Counter.* F. B. HARRISON AND GEORGE T. REYNOLDS, *Princeton University.*—The uniformity of response of a selected single crystal of sodium iodide (1 percent thallium iodide impurity) mounted on a 931 A photomultiplier has been tested by means of cosmic ray mesons. A combined scintillation and geiger counter telescope selected mesons whose energy losses in the crystal corresponded to ionization within 3 percent of minimum. Thus all pulse heights observed should be the same. Because of the severe geometrical conditions imposed, the counting rate was only 1 every 4 hours. The results of the first 150 hours of operation show all pulse heights to be within 30 percent of the average, except 6 which may be accounted for on the basis of side showers. A subgroup of pulses obtained during a period in which operating conditions were known to be more uniform than over the whole 150 hour period gave pulse heights within 20 percent of the average.

* Supported by joint program of Office of Naval Research and Atomic Energy Commission.

H2. Measurements of Meson Decay by Scintillation Counters.* GEORGE T. REYNOLDS AND F. B. HARRISON, *Princeton University.*—Scintillation counter experiments previously reported[1] have been extended to measurements of meson decay times. In the present apparatus it is possible to determine the decay time in absorbers of various atomic numbers, independently of the crystal material used. Measurements obtained using lead as absorber are in good agreement with the accepted mean life. Sodium iodide and napthalene have been used as crystals in these measurements. Hofstadter[2] has shown that pulses from stilbene have a decay time of less than 2×10^{-8} sec. A large stilbene crystal has been prepared for the present experiment and will permit time resolution of the order of 4×10^{-8} sec. Because the scintillation counter has a high efficiency for γ-rays, this short time resolution permits a search for γ-rays which may result when negative mesons are captured.[3]

* Supported by joint program of ONR and AEC.
[1] George T. Reynolds, Bull. Am. Phys. Soc. **24**, No. 1, 49 (1949).
[2] Hofstadter, Milton, and McIntyre, Bull. Am. Phys. Soc. **24**, No. 1, 16 (1949).
[3] W. Y. Chang, Bull. Am. Phys. Soc. **24**, No. 1, 47 (1949).

H3. Interactions of Ionizing Cosmic-Ray Particles at 10,600 ft. Altitude.* JOHN TINLOT AND BERNARD GREGORY, *Massachusetts Institute of Technology.*—A large square cloud chamber was operated at Echo Lake, Colorado (elevation 10,600 ft.), to study the properties of ionizing cosmic-ray particles capable of penetrating one inch of lead. The chamber contained seven lead plates $\frac{1}{4}''$ thick and six aluminum plates $\frac{5}{16}''$ thick, arranged alternately. A narrow counter telescope above the chamber was used to trigger expansions; only particles which could pass through the telescope were considered in the analysis. In a preliminary study of about 3600 pictures, we found 37 nuclear explosions (25 in lead, 12 in aluminum), 25 cases of nuclear scattering of fast particles, 79 examples of particles stopping in the chamber, and 8 narrow electron showers (presumably caused by a single energetic electron or photon). In addition, there were 18 cases of nuclear explosions apparently caused by non-ionizing particles, but possibly associated with the triggering particles. From these data (and making use of the known meson intensity at this altitude) an estimate of the intensity of the so-called ionizing *N*-rays can be made.

* This work was supported in part by the joint program of the ONR and the AEC.

H4. Further Experiments on Sea-Level Mesons Stopped at Thin Pb Foils.* W. Y. CHANG, *Palmer Physical Laboratory, Princeton University.*—By increasing cloud chamber depth and telescopic solid angle, the number of mesons entering the chamber via telescope has been increased to 150 per hour, 2–3 times larger than that in the previous cases.[1] Six 0.009-inch and five 0.018-inch Pb foils (not covered with Al foils) have been put alternately inside the chamber. The following results have been obtained over 800 hours: (1) 26 stopped negative mesons have been obtained, giving off no observable charged particles from the ends. This confirms the conclusion of our former experiments that no protons were emitted when μ-mesons interacted with Pb nuclei. (2) 9 pictures of the 26 stopped μ^- show meson-oriented secondary electron tracks (1–4 Mev). This ratio is again much larger than the "chance orientation" of the stray electrons, giving further evidence of the low-energy gamma-rays from stopped negative μ-mesons (mesonic orbits and small nuclear excitation). (3) The fact that no decay electron (from over 40 decay pictures) has been observed to move toward any one of the anticoincidence counters below the chamber (5 g/cm² wall, etc.) argues for few low-energy decay electrons. The proportion of decay electrons below 10 Mev is concluded to be of the order 1 in 30 or less.

* Assisted by the joint program of the AEC and ONR.
[1] W. Y. Chang, Bull. Am. Phys. Soc. **24**, No. 1, 47 (1949); Rev. Mod. Phys. **21**, 166 (1949).

H5. The Production of Mesons in the Stratosphere.* MARCEL SCHEIN AND J. J. LORD, *University of Chicago.*—Measurements in the high atmosphere with photographic plates indicate that the number of mesons stopping in the emulsion is very much dependent upon the location and quantity of nearby material. One centimeter of lead above a plate increases the number of π-mesons by at least a factor of 15. At the same time the number of μ-mesons increases by only a factor of 3 to 4. The ratio between the number of π-mesons stopping in the emulsion placed below the lead and that of stars occuring in the same plate is 1 to 10, as contrasted with the value of about 1 to 1000 found at Berkeley using the high energy neutron beam.[1] The number of positive mesons exhibiting a $\pi-\mu$-decay is roughly the same as the number of π-mesons producing stars at the point where they stop in the emulsion.

* Assisted by the joint program of ONR and AEC.
[1] C. M. G. Lattes (private communication).

H6. Magnetic Deflection of Mesons in Photographic Plates.* I. BARBOUR, *University of Chicago.*—A method for determining the mass and charge sign of mesons has been described[1] in which two nuclear plates are exposed, with an air gap of 3 mm between their parallel emulsion surfaces, in a perpendicular magnetic field. From the orientation of the tracks of a given particle in the two emulsions, is computed the radius of magnetic curvature of the trajectory in the intervening air gap, and hence the momentum, which, with the range, gives the mass. With a permanent magnet weighting 65 lbs., field strength 13,300 gauss, flights of 2 hrs. at 90,000 ft. show about 75 mesons on the 15 in.² of 100μ Ilford C2 emulsion, which contains extra plasticiser to reduce surface distortion. After development, a pantagraph attached to the microscope stage plots location and orientation of tracks relative to a registration grid of x-ray spots. Angle measurements of heavy particles and fast protons agree to 1°, whereas mesons often

show deflections of the order of 10°; cases of long trajectories and long residual ranges allow more accurate determinations. Some preliminary mass measurements will be given.

* Assisted by the joint program of ONR and AEC.
[1] C. F. Powell, Nature **161**, 473 (1948); I. Barbour, Phys. Rev. **74**, 507 (1948).

H7. "Off-Scale" Bursts under 26.7 cm Lead at an Altitude of 3500 Meters.* EDWARD F. FAHY AND MARCEL SCHEIN, *University of Chicago.*—During 1424 hours of large burst observations, made with a Carnegie Model "C" meter under a spherical shield of 26.7 cm of lead at Climax, Colorado, four bursts were observed which deflected the electrometer needle off scale. These bursts had an ionization equivalent of more than 4000 singly charged particles at minimum ionization. Three of these "off-scale" bursts occurred simultaneously with giant atmospheric showers which were detected by means of shower counting coincidence sets of G-M counters placed on a horizontal plane over the lead shield. Bursts of less than 1000 particles show no detectable correlation with air showers. It is of interest to note than an atmospheric shower which is produced at the top of the atmosphere and which has more than 4000 particles after passing through 26.7 cm Pb (53 radiation units) should carry an energy much greater than the energy of any single event which has been observed so far in the cosmic radiation.

* Assisted by the joint program of ONR and AEC.

H8. The Density Effect for Cosmic Ray Mesons.* W. L. WHITTEMORE AND J. C. STREET, *Harvard University.*—Using a specimen of silver chloride as an ionization detector and examining with a linear amplifier the pulses produced by mesons, we have been able to investigate experimentally the net rise in the rate of ionization in the relativistic energy region as modified by the density effect. An arrangement of lead filters was used to select two groups of mesons, one ionizing at the minimum rate and the other ionizing at a rate corresponding to mesons with ranges greater than 112 cm of lead. The distribution of pulses for each group is compared with the distribution of energy loss predicted by the fluctuation theory of Symon, which does not contain a correction for the density effect. The agreement between measured and calculated relativistic increase of ionization is poor; but, when a reasonably chosen correction for the density effect (determined empirically but following the general course of the curves of Halpern and Hall[1]) is applied to the Symon distribution, close agreement between experiment and theory can be obtained. Comparison of the empirical correction for silver chloride with the calculations of Halpern and Hall for other materials will be made.

* This work is supported by Navy contract.
[1] O. Halpern and H. Hall, Phys. Rev. **73**, 477 (1948).

H9. The Nature of the Penetrating Particles in Extensive Showers.* FRANK L. HEREFORD, *Bartol Research Foundation.*—The existing experimental results concerning the penetrating component of extensive cosmic-ray showers have received widely varying interpretations as regards identification of the penetrating particles. The penetrating component is generally thought to consist of a mixture of mesons and nuclear particles, presumably protons. An attempt has been made to determine the intensity of these nuclear particles by utilizing the dependence of the counting efficiency of a low pressure Geiger counter upon the specific ionization of a counted particle. A tray of such low pressure counters, placed beneath 20 cm of lead and shielded on all sides, was operated in a shower-selective coincidence system. The coincidence arrangement allowed measurement of the counting efficiency of this counter tray for single penetrating shower particles. Through comparison with the measured counting efficiency for the total ionizing component at sea level, preliminary data indicate that particles heavier than μ- or π-mesons comprise at the most only a few percent of the penetrating component of extensive showers. This result is in agreement with that recently obtained by Cocconi, Cocconi, and Greisen.[1]

* Supported by the Joint Program of ONR and AEC.
[1] Unpublished results communicated by Dr. K. Greisen.

H10. Altitude and Latitude Dependence of Nuclear Disintegrations Measured in Photographic Emulsions in the Stratosphere.* J. J. LORD, MARCEL SCHEIN, AND M. VIDALE, *University of Chicago.*—The rates at which nuclear disintegrations occur has been measured at 5 cm, 3.2 cm and 1.05 cm of Hg pressure using Ilford C2 Boron loaded plates 100 microns in thickness. The measurements were made from 51° to 56° north magnetic latitude and comparing these rates with those of Powell and his collaborators,[1] shows that the absorption coefficient is uniform at 148 g per cm^2 to the highest altitudes (1.05 cm of Hg). Nuclear disintegration rates measured under identical conditions at approximately 1.1 cm of Hg pressure show that the intensity falls by a factor of 4.4 in going from 56° north to 30° north magnetic latitude.

* Assisted by the joint program of ONR and AEC.
[1] Lattes, Occhialini, Powell, Nature **160**, 486 (1947).

H11. Variation of Cosmic Star Production with Altitude. HERMAN YAGODA, NATHAN KAPLAN, AND C. H. CONNER, *National Institutes of Health.*—Emulsions exposed at 48 to 50°N geomagnetic latitude exhibit the following star populations (2 or more prongs) E per cc per day: Sea level, Bethesda, Md. = 0.53 to 0.29 depending on type housing; 1230 m, Bickles Knob, West Va. = 2.0; 3260 m, Echo Lake, Col. = 10.8; 3500 m, Climax, Col. = 13.8; 27,400 m stratosphere above Minn. = 1400. The populations between sea level and the stratosphere are related approximately by $\log_{10}E = 3.12 - 0.00313D$ where D is the atmospheric depth in g cm^{-2}. The absorption coefficient for air based on three mountain top exposures is $1/(143 \pm 3)$. Statistics on 92 sea level stars indicate same multiplicity pattern as observed in plates on mountain tops. The number of tracks per star is appreciably greater in stratosphere exposures than below 3500 m. An event showing the emission of a $\sim 1000 m_e$ particle from a complex evaporation and decaying in the emulsion with the production of ionizing secondaries will be described.

H12. Delayed Proton-Electron Activity Induced in Aluminum by Non-Ionizing Cosmic Rays. E. C. FOWLER, R. L. COOL, AND J. C. STREET, *Harvard University.*—A cloud chamber with illuminated volume 18″ in diameter and 5½″ deep fitted with three 1 cm lead plates and eight 0.020 cm aluminum foils has been run with counter control (selecting cosmic-ray showers) and with clock control (random operation with respect to cosmic-ray events) at Cambridge[1] and Climax, Colorado (altitude 11,200 ft.). The photographs obtained contain many examples of an event in which a proton with a range of about one foil (energy equals 5.2 Mev) and an electron with energy less than 0.5 Mev emerge simultaneously (within the resolution of the cloud chamber) from a point in the aluminum. The rates observed in the different runs differ sufficiently to show that shower selection favors the observation of the proton-electron event. No other directly associated tracks are observed. With shower selection this event is seen to occur with various delays from the time the counters were fired out to the end of the chamber's sensitive time. The Cambridge run was too short to give a quantitative altitude change. Examination of the random expansions at Climax continues. Additional information supporting the above conclusions will be presented.

[1] E. C. Fowler, R. L. Cool, and J. C. Street, Phys. Rev. **74**, 101 (1948).

THURSDAY AFTERNOON AT 4:45

Departmental Auditorium

(I. I. RABI presiding)

Invited Paper

H13. Recent Developments in the Quantum Theory of Fields. F. J. DYSON, *Institute for Advanced Study.* (40 min.)

THURSDAY AFTERNOON AT 2:15

East Building, National Bureau of Standards

(I. I. RABI presiding)

Invited Paper

I1. (Title to be announced.) A. M. J. F. MICHELS, *Van der Waals Laboratory, Amsterdam, Holland.*

Fluid Dynamics

I2. On a Method of Measurement of Some Characteristics of Turbulence Using Non-Compensated Hot-Wires.* F. N. FRENKIEL, *Naval Ordnance Laboratory.*—Let us consider a hot wire anemometer with a wire of negligible length and an amplifier including a compensation unit for the thermal lag of the wire. We denote by E the longitudinal component of the turbulent energy ($E=\frac{1}{2}\rho\langle u'^2\rangle_M$), as obtained from measurements with the compensation on, and by E_c the corresponding energy as measured with the compensation off. It is found** that $E_c/E=\int_0^\infty[f_t(s)/1+M^2s^2]ds$ where $f_t(\omega)$ is the spectrum of turbulence at a point and M the time constant of the wire. After assuming some given spectra or correlation curves, the factor E_c/E is expressed as a function of $\Lambda_t=ML_t$ (L_t-time scale of turbulence). The value of L_t can then be obtained using a wire of a known time constant and measuring the turbulent energy with and without compensation. When the spectrum $f_t(\omega)$ is considered to be equal to the longitudinal spectrum $f_x(\omega)$, the same method can be used to find the longitudinal scale of turbulence L_x. This method of measurement can be used for rapid determination of an approximate value of the scale of turbulence. Other characteristics of turbulence can be also found using non-compensated hot wires.

* Sponsored by ONR.
** F. N. Frenkiel, Comptes Rendus **222**, 585 (1946).

I3. Momentum Thickness Development in a Turbulent Boundary Layer at $M-1.7$.* D. BERSHADER, *Princeton University.*—Using the technique of interferometry, density profiles have been evaluated in a turbulent boundary layer along the wall in the uniform flow region of a rectangular Laval nozzle discharging air from a pressure tank into the atmosphere. By means of the density values and certain assumptions, velocity profiles were calculated. The momentum thickness, θ, is defined in terms of these quantities by

$$\theta=\int_0^\delta \frac{\rho u}{\rho_1 u_1}\left(1-\frac{u}{u_1}\right)dy$$

where ρ and u are the variable density and velocity in the boundary layer, ρ_1 and u_1 the corresponding free stream values, and δ the width of the boundary layer. Plotting obtained values of θ against x (direction of flow) gives the result that $d^2\theta/dx^2>0$. This is in disagreement with what is to be expected when the skin friction formula for turbulent incompressible flow is used in the momentum equation. These experiments were carried out at a momentum thickness Reynolds number $\mathrm{Re}=5\times10^3$. The work so far is preliminary and is being extended to other Mach and Reynolds numbers by Professor R. Ladenburg and the author using a 3 inch supersonic intermittent wind tunnel together with a 5 inch Mach-Zehnder type interferometer.

* Performed under a contract with ONR.

I4. Factors Affecting the Production of Steady Flow Past Models in the Shock Tube. C. W. MAUTZ, *University of Michigan.*—The duration of steady flow in the test section of a shock tube is sharply dependent on the shock strength. The conditions under which steady flow *past a model* can be produced were studied, using apparatus previously described,[1] by following the motion of detached bow-waves formed by wedges of $\frac{1}{16}$-, $\frac{1}{8}$-, and $\frac{1}{4}$-inch thickness with 30- and 45-degree wedge angles. With the arrival of the shock front at the model, the bow-wave begins to move upstream toward an equilibrium position if $1<M<M_e$, where M is the Mach number in the shock wave, M_e is the Mach number which produces an attached bow-wave. The Mach number was varied in steps of 0.05 from 1.2 to 1.5. The combinations of Mach number, wedge thickness, and wedge angle for which the separation of the bow-wave from the model reached a steady value in the time available will be discussed.

[1] Mautz, Geiger, and Epstein, Phys. Rev. **74**, 1872 (1948).

I5. Oblique Reflection of Low Amplitude, Exponential Shock Waves from the Sea Bed.* A. B. ARONS AND D. R. YENNIE, *Woods Hole Oceanographic Institution and Stevens Institute of Technology.*—Experimental measurements of underwater explosions have shown a progressive distortion of the form of the wave reflected from a firm, sandy bottom when the angle of incidence exceeds a certain critical angle. The incident wave consists of a shock front followed by essentially exponential pressure decay. The distorted reflected wave shows a gradual pressure rise to a very high peak, followed by a sharp drop to negative pressures. In the limit of angles of incidence

approaching 90°, the reflected wave tends to become a "mirror image" of the incident wave, as though the reflection were taking place at a free surface. The phenomenon is accounted for by an acoustical treatment which predicts a phase shift of the reflection of a simple harmonic wave when the critical angle for total reflection is exceeded. The phase shift is independent of frequency and depends only upon the angle of incidence and the densities and sound velocities of the two media. When this phase shift is applied to the Fourier spectrum of the exponential pulse, it is shown that the resulting theoretical pressure-time curves correspond very closely to those observed experimentally.

* Work performed under contract with the Navy Department, Bureau of Ordnance.

X-Rays

I6. Determination of the Energy Distribution of Bremsstrahlung from 19.5 Mev Electrons.* H. W. KOCH, R. E. CARTER, AND C. S. ROBINSON, *University of Illinois.*—The bremsstrahlung spectrum has been measured for 19.5 Mev electrons produced by a betatron and directed against a thin target. The relative intensity of the x-rays as a function of energy was determined from the number of pairs of various energies produced in the gas (air) of a cloud chamber. A 0.005" thick platinum target was the source of the x-rays which passed through a lead collimator. The magnetic field at the chamber was 1540 gauss. Approximately 1600 pairs survived the selection criteria and permitted a test of the predicted Bethe-Heitler spectrum in the forward direction as communicated by Schiff. The experimental numbers of quanta in the high energy half of the spectrum are relatively greater than the predicted values. The statistical methods of handling a continuous distribution, the means of correcting for the experimental discrimination in pair energy, and the general application of a cloud chamber to continuous x-ray spectra determinations will be discussed. Some interesting details of the pair production process which were measured will also be presented.

* Assisted by the joint program of ONR and AEC.

I7. Absorption by Aluminum between 100A and 300A. E. M. PELL AND D. H. TOMBOULIAN, *Cornell University.*—The structure of the aluminum absorption curve on the short wavelength side of the $L_{II,III}$ edge was examined, using a capillary spark discharge to produce the incident radiation. The absorber was prepared by evaporating aluminum on one of two identical Zapon films whose transmission was about 50 percent at 300A and much greater at shorter wave-lengths. The two samples were so mounted that either of the specimens could be placed behind the slit of the spectrograph, making it possible to photograph on the same plate juxtaposed spectra of the radiation transmitted by the absorbing sample and by the backing film alone, and permitting the sparks producing the exposure to be intermingled between the two spectra. The general features of the absorption curve resemble those previously observed by Johnston[1] except in the following features: The jump in the absorption coefficient at the $L_{II,III}$ edge at 170A is 10×10^4 cm^{-1}. At approximately 106A there is a strong suggestion of a somewhat diffuse edge. The authors wish to thank Professor L. G. Parratt for helpful discussions. The work was carried out under contract with ONR.

[1] J. E. Johnston, Proc. Camb. Phil. Soc. **35**, 108 (1939).

I8. On the Position of L_I Absorption Edge in Aluminum. D. H. TOMBOULIAN AND E. M. PELL, *Cornell University.*—Based on tentative identifications[1,2] of radiative transitions within the L shell of several light elements, the term value of the L_I level in aluminum should lie about 115 ev below the top of the filled conduction band. Although L_I emission bands are too weak to be observed, absorption measurements should show evidence of the L_I edge. The absorption curve as determined by the measurements described in the previous paper indicates a diffuse "edge" approximately at 106A in agreement with the expected position of the L_I level. The jump in the absorption coefficient at this wave-length is 6×10^4 cm^{-1}, which is considerably smaller than the $L_{II,III}$ jump. Further measurements using a different source are contemplated in order to verify the present observations. The work was carried out under contract with ONR.

[1] D. H. Tomboulian and W. M. Cady, Phys. Rev. **59**, 422 (1941).
[2] D. H. Tomboulian, Phys. Rev. **74**, 1887 (1948).

I9. Simultaneity in the Compton Effect.* R. HOFSTADTER AND J. A. MCINTYRE, *Princeton University.*—We have constructed an apparatus to study the Compton effect and the angular distribution of scattered gamma-rays predicted by the Klein-Nishina formula. In our first experiment we have re-examined the question of whether the recoil electron and scattered photon are produced simultaneously. We have studied coincidences between two stilbene scintillation counters employed as scatterer and detector respectively. A small stilbene scatterer, placed in the ($\frac{1}{8}''\times\frac{1}{8}''$) Co^{60} gamma-ray beam provides the recoil electron pulse, while a larger stilbene detector crystal records the scattered photon. The detector crystal subtends at the scatterer a plane angle of ten degrees or less and may be placed at various angles with respect to the direction of the incident Co^{60} ($\sim$1.2 Mev) gamma-ray beam. A coincidence is detected visually and photographically on an oscilloscope screen as a characteristic double pip, obtained by delaying the crystal pulses by different amounts and using the detector pulse to trigger the sweep. With this technique we may detect time differences of about 5×10^{-8} second. Within this time the experiment demonstrates simultaneity, in agreement with the early work of Bothe and Geiger who found simultaneity within 10^{-3} second.

* This work was assisted by the Joint Program of ONR and AEC.

THURSDAY EVENING AT 7:00

Ballroom, Mayflower Hotel

(F. W. LOOMIS presiding)

Banquet of the American Physical Society

After-dinner speech by **E. U. CONDON**, *National Bureau of Standards.*

Chamber Music

FRIDAY MORNING AT 10:00

East Building, National Bureau of Standards

(H. SPONER presiding)

Spectroscopy, Atomic and Molecular

K1. Electron Screening, Electron Quantum Numbers, and Ionization Potentials of Atoms and Ions. WOLFGANG FINKELNBURG, *Engineer Research and Development Laboratories.*—The screening of the nuclear charge Z of any atom or atomic ion, by all its electrons with respect to the outermost one, can be calculated from the spectroscopic ionization energies of atoms and ions. By tabulating the change of this screening constant, Δs, from element to element in the Periodic Table, the author has found striking regularities, these Δs values either being constant or varying regularly within each group of the Periodic Table. Quite a number of conclusions can be drawn from these regularities. In the first place, unknown ionization potentials can be interpolated with a fair amount of accuracy, wrong ones can be corrected. Secondly, a very surprising, and as yet theoretically unexplained, relation between the spin direction of the outermost electron and the screening constants has been found. Quite generally, there exist close relations between the screening constants and the quantum numbers of the outermost electron. They indicate, for instance, that either the presently known values of the ionization potentials of the rare earth atoms or their electron quantum numbers are incorrect.

K2. The Effect of Finite Aperture on the Fringe Intensity Distribution of Fabry Perot Interferometers.* FELIX E. GEIGER, JR., *University of Wisconsin.*—The effect of the finite aperture of a Fabry Perot interferometer on the fringe intensity distribution in the interferometer pattern is investigated. An equation is derived for a square etalon which illustrates clearly the decrease in fringe intensity for increasing angles of incidence. The computations show that this effect becomes significant only for high reflecting powers and comparatively large plate separations.

* Supported by Navy contract.

K3. Forbidden Absorption Lines from Extraordinarily Large Orbits in Alkali Metal Atoms.* H. R. KRATZ** AND J. E. MACK, *University of Wisconsin.*—Long-path, low-temperature absorption spectrograms show forbidden $s-nd$ lines up to $13d$ for K I, and to $21d$ with resolved ^2D structure to $16d$ in Cs I. Plates taken through 24 meters of rubidium vapor at 278°C show forbidden $5s-n1$ lines of Rb I, with $n1$ extending not only to $54d$, but also from $29f$ to $50f$ and from $29q$ to $47q$, where q stands for the 1-value of a non-penetrating orbit ($1>3$). The forbidden $s-nf$ or $s-nq$ or absorption lines appear only for final states of atoms (taken as spheres of radius $n_{eff}^2 a_1$, where a_1 is the radius of the first Bohr orbit) so large as to include, on the average, several other atoms of the gas; microscopic fields from these enveloped atoms might be sufficiently important to account for the violation of the selection rules in the macroscopically field-free gas as a collision phenomenon. On the other hand, $\lambda_{absorption}/2\pi$ equals the atomic radius for $n=30$, which might lead to large multipole transition probabilities.

* The computations were aided by Navy contract.
** Now at the General Electric Research Laboratory, Schenectady, New York.

K4. The Absorption Spectrum of Atomic Sodium. E. R. THACKERAY,* *University of Wisconsin.*—Using a long optical path attained by the method of Kratz and Mack, the wavelengths of the principal series of sodium in absorption have been measured to $n=73$, and observed to $n=79$. The members to $n=9$ have been resolved. The series limit has been computed to be 41449.65 ± 0.02 cm^{-1} from the center of gravity or 41449.69 ± 0.02 cm^{-1} from the lower hyperfine structure component, of the $3s\,^2S_{1/2}$ term. Forbidden $3s\,^2S_{1/2}-nd\,^2D_{3/2,\,5/2}$ transitions have been measured to $n=13$. A critically compiled table of all known levels, including $np\,^2P_{1/2,\,3/2}$ to $n=73$ and $nd\,^2D_{3/2,\,5/2}$ to $n=13$, is given. The pressure shift from a foreign gas is less than reported by some earlier observers.

* Now at Regina College, Regina, Saskatchewan.

K5. Hollow Cathode Tube Design for Spectroscopic Hyperfine Structure Studies with Small Samples.* O. H. ARROE AND J. E. MACK, *University of Wisconsin.*—An aluminum cup is clamp-sealed directly to a 1-inch inconel tube 30-mm long, water-warmed at the top and fitted to 40/12 inner-half ground glass joint. Above the joint is an inner seal with a sleeve tube extending down to the cup. A waxed-on window less than 50 mm above the cup allows passage of a cone-shaped beam from the cup with a divergence greater than 1/3. A side tube leads to a charcoal-trap, which can be immersed beside the tube in one large-mouthed dewar, and to a small regulated rare-gas supply. The system can be evacuated with a mechanical pump. Rich spectrograms can be made of samples of the order of 1 mg. The simplicity, compactness, and portability of the tube, with the avoidance of diffusion pumps and cumbersome circulating apparatus, are especially advantageous when several sources, as for instance different isotopes, are to be compared.

* Supported by Navy contract.

K6. Hyperfine Structure and Isotope Shift Studies, Especially of the Nuclear Spin of Se^{77}.* J. E. MACK AND O. H. ARROE, *University of Wisconsin.*—The fine structure of the SeII lines $\nu\nu$18103 and 20092, studied in natural-abundance and 77-enriched samples with etalon spacers up to 40 mm, show convincingly that the spin of Se^{77} has a value greater than the $\frac{1}{2}$ that has crept into the literature. In order to reconcile the value $\frac{1}{2}$ with our (incompletely resolved) spectrograms it would be necessary to make the unattractive postulate for each line, that while the shift among the even isotopes is so small as not to affect the apparent Doppler width ($\sim$0.022 cm^{-1}) appreciably, the centroid of the 77 isotope is shifted about 0.015 cm^{-1} from that of the even isotopes. In zinc, progress has been made in the study of the isotope shift.

* Supported by Navy contract.

K7. Isotope Shift in the HeI Spectrum. THURSTON E. MANNING, *Yale University.*—The isotopic structure of lines in the spectrum of neutral helium has been observed in the first order of a grating giving a reciprocal dispersion of 1.25 A/mm. The spectrum was excited in a water-cooled Geissler tube using helium enriched in He^3 by the method of Reynolds *et al.*[1] Visual observation and microdensitometer traces show a satelite to the long wave-length side of the He^4 lines that is identified as He^3. Measurements of these lines show approximate shifts of 1.35 cm^{-1} for λ6678, 1.18 cm^{-1} for λ5048, and less than 1.20 cm^{-1} for $\lambda\lambda$5016, 4922. These values are considerably higher than theoretical values calculated from the Hughes-Eckart approximation,[2] and the discrepancies do not seem to be explained as experimental error;

this agrees with interferometric measurements on λ5016 by Bradley and Kuhn.[3] The relation of this work to that of Andrew and Carter[4] on λ6678 will be discussed.

[1] C. A. Reynolds *et al.*, this bulletin.
[2] D. S. Hughes and C. Eckart, Phys. Rev. **36**, 694 (1930).
[3] L. C. Bradley and H. Kuhn, Nature **162**, 412 (1948).
[4] A. Andrew and W. W. Carter, Phys. Rev. **74**, 838 (1948).

K8. Electron-Nuclear Potential Fields from Hyperfine Structure. A. L. SCHAWLOW AND M. F. CRAWFORD, *University of Toronto.*—Rosenthal and Breit and Racah formulated a relativistic theory of the effects of finite nuclear size, with the consequent departure from a Coulomb field, on the atomic energy levels and on the interaction between electrons and nuclear magnetic moments. The first effect leads to an isotope shift, and the second to a correction for the nuclear magnetic moment deduced from hyperfine structure splittings. The experimentally measured isotope shifts for unperturbed levels arising from *ns* configurations of HgII, TlIII, PbIV are analyzed and found to be proportional to $\psi^2(0)$ as predicted. The magnitudes of the observed shifts give the same relative change in nuclear radius. The validity of the perturbation method and screening of inner completed electron shells by the valence electron are considered. Induction values of nuclear magnetic moments for thallium are 15 percent higher than the spectroscopic. Agreement is obtained when the spectroscopic values are corrected for the finite nucleus with a uniform charge distribution.

K9. The Source of Highly Forbidden Lines in CdI.* FERNAND E. DELOUME AND JOHN R. HOLMES, *University of Southern California.*—The transitions $n^3P_0-n^1S_0$ and $n^3P_2-n^1S_0$ in atomic spectra are forbidden by all selection rules. Nevertheless these "forbidden" lines are observed in Hg, Cd and Zn. Bowen[1] suggested that they arise from the odd isotopes because of the nuclear magnetic moment. Mrozowski[2] studied the line λ2656A ($6^3P_0-6^1S_0$) in Hg and found two components corresponding to the two odd isotopes, but their relative intensities are not the same as the relative abundances. To investigate independently Bowen's suggestion, a Cd sample enriched in Cd^{111} to 64.5 percent (courtesy of AEC) was excited in an electrodeless discharge so that the lines λ3320A $\times(5^3P_0-5^1S_0)$ and λ3141A($5^3P_2-5^1S_0$) appeared strongly. The intensities of these lines were compared with the same lines from an unenriched sample (odd isotope 25.3 percent) identically excited. In the enriched sample the intensities of the lines were found to be increased in proportion to the increase in abundance of the odd isotope.

* Work partly supported by ONR.
[1] I. S. Bowen, Rev. Mod. Phys. **8**, 55 (1936).
[2] S. Mrozowski, Rev. Mod. Phys. **15–16**, 153 (1943–44).

K10. Hydrogen Bonding and Isomeric Forms in Bis-Phenols. NORMAN D. COGGESHALL, *Gulf Research & Development Company.*—The hydrogen bond is known to be a strong force of attraction between hydroxyl groups. It is the result of the uneven distribution of valence electrons between the hydrogen and oxygen atoms of the hydroxyl groups which gives rise to electrostatic and dipole-dipole forces. Hydrogen bonding may be inter-molecular, i.e. between different molecules, or intra-molecular, i.e. between polar groups within the same molecule. It is conveniently studied by means of infra-red absorption spectroscopy. The fundamental absorption frequency of the hydroxyl group decreases changes as the group becomes hydrogen bonded. Such a study has been made of a series of bis-phenols. A bis-phenol comprises two phenolic nuclei bridged through an aliphatic group. These compounds are found to exist in three states: a *cis* isomeric form, a *trans* isomeric form, and inter-molecularly bonded. The *cis* form corresponds to an orientation, through rotation of the valence bonds joining the phenolic nuclei to the bridging group, such that the hydroxyl groups on the two phenolic nuclei are hydrogen bonded. The *trans* form corresponds to an orientation such that the hydroxyl groups are not under the influence of each other and yet are not inter-molecularly bonded. The distribution among the various states was found to depend primarily upon the nature of the bridging group and the form of substitution. If the bridging is through a 1,1 substitution on the bridging group both *cis* and *trans* forms are found.

K11. Spectroscopic Investigation of the Carbon Monoxide-Oxygen Reaction.* GEORGE A. HORNBECK AND HELEN S. HOPFIELD, *The Johns Hopkins University.*—Some of the characteristic flame bands of CO-oxygen combustion, which were previously attributed to the CO_2 molecule, have been identified as the Runge bands, which are due to the $^3\Sigma_u^-\rightarrow{}^3\Sigma_g^-$ transition of the neutral oxygen molecule. The so-called "atmospheric absorption" bands, due to the $^1\Sigma_g^+\rightarrow{}^3\Sigma_g^-$ transition of neutral O_2, have also been obtained in emission. Spectrograms of these bands were obtained from both the self-sustained and explosion flames of CO and oxygen. Additional spectroscopic information on the OH radical in flames has been obtained.

* The work described in this paper has been supported by the Bureau of Ordnance, U. S. Navy.

FRIDAY MORNING AT 9:30

Department of Commerce

(W. SHOCKLEY presiding)

Solid-State Physics, Including Magnetism

L1. Study of Transient Stresses in Photoelastic Media. JOHN S. STANTON, *Naval Ordnance Test Station, Pasadena.*—A technique for measuring transient stresses in photoelastic media has been reported.[1] Studies using this technique are applied to: (a) measuring the velocity of stress waves in Plexiglas, (b) studying the effect of cavities within the model, (c) assessing the effect of surface waves in plastic, (d) measuring the lag with which the photoelastic pattern follows initiation of stress in the model, (e) studying the effect of embedding metals in the plastic, (f) observing the phenomena accompanying spreading of the wave into a widened section, (g) studies in birefringent fluids, and (h) the effect of temperature on Plexiglas models.

[1] J. S. Stanton, Rev. Sci. Inst. **20**, 139 (1949).

L2. Spectral Emissivity and Conductivity of Titanium.[1] WALTER C. MICHELS AND SALLY E. WILFORD, *Bryn Mawr College.*—Measurements have been made on two samples,

rolled rod and 17 mil wire, of 99.5 percent pure titanium.[2] The spectral emissivity (0.665μ) was determined by comparison with the brightness of a black body over the range from 1050°K to 1400°K. The resistivity was measured from room temperature to 1400°K. At 20°C the resistivity is 77 ohm cm and the temperature coefficient is 0.0026 per degree. The resistance follows a $T^{0.75}$ law quite precisely up to 600°K, but above this it increases less rapidly with increasing temperature and shows a flat maximum in the neighborhood of the reported transition at 1153°K. The maximum resistivity is 183 ohm cm. At still higher temperatures the temperature coefficient is a small, but measurable, negative quantity. The spectral emissivity shows a minimum value of about 0.59 in the region of maximum resistance.

[1] This work is assisted by a Frederick Gardner Cottrell Grant from the Research Corporation.
[2] Supplied by Mr. C. I. Bradford of the Remington Arms Company.

L3. Thermo-Optic Properties of Cubic Crystals. ELIAS BURSTEIN AND PAUL L. SMITH, *Naval Research Laboratory.*—Data on the change in refractive index with density at constant temperature, $(\partial n/\partial \rho)_T$, yield information about the change in the average polarizability of the atoms with change in equilibrium interatomic distance.[1] Further information about the dynamic changes in polarizability can be obtained by combining $(\partial n/\partial \rho)_T$ data with data on the change in refractive index with temperature, dn/dT. This yields data on the change in refractive index with temperature at constant density, $(\partial n/\partial T)_\rho$, and on the change in the average polarizability of the atoms with temperature. The changes in polarizability can be correlated with shifts in the absorption frequencies and changes in the transition probabilities. From available photoelastic and thermo-optic data for the alkali halides it is shown that the density contribution to the change in polarizability with temperature is larger than the temperature contribution. It is concluded that the shift in absorption frequencies in the alkali halides with change in temperature results primarily from density effects.

[1] H. Mueller, Phys. Rev. **47**, 947 (1935); E. Burstein and P. L. Smith, Phys. Rev. **74**, 229 (1948), Proc. Ind. Acad. Sci. **A28**, 377 (1948).

L4. Radial Density Function for Crystals from X-Ray Intensity Data.* WILLIAM J. TAYLOR, *The Ohio State University.*—A radial electron-density function for crystals may be obtained by averaging the Patterson vector function over all orientations. The radial function is

$$R(r)-R(\infty)=\sum_{i=1}^{\infty}\phi(s_i)\frac{\sin 2\pi s_i r}{2\pi s_i r}$$

$0<s_1<s_2<\cdots$ are the distinct values of the reciprocal interplanar distances, d_{hkl}^{-1}, which occur in the lattice. $\phi(s_i)$ is the sum of all $|F_{hkl}|^2$ for which $d_{hkl}^{-1}=s_i$. $\phi(s_i)$ is obtained directly from the integrated intensity of the corresponding line in the powder diffraction pattern, using the relation $s_i=2\sin\theta_i/\lambda$. $R(\infty)=|F_{000}|^2$ is the square of the average electron density. The Fourier cosine transform,

$$\psi(s)=\int_0^\infty [R(r)-R(\infty)]\cos 2\pi s r dr$$

is a *step function*, such that $\phi(s_i)=4s_i[\psi(s_i-0)-\psi(s_i+0)]$, and the powder diffraction pattern of a crystal is therefore uniquely determined by the radial function. The radial function should have some application to the determination of interatomic distances in molecular crystals.

* This work was carried out in The Ohio State University Cryogenic Laboratory under contract between the Office of Naval Research and The Ohio State University Research Foundation.

L5. An X-Ray Diffraction Study of the Gold-Beryllium Alloy System.* G. P. CHATTERJEE AND S. S. SIDHU, *University of Pittsburgh.*—Forty-two samples of gold-beryllium alloys, varying from 0 to 100 atomic percent beryllium in composition and prepared by two different methods, were studied both by the powder and the back-reflection x-ray diffraction methods. A few selected samples were examined with a microscope. The beryllium used in making the alloys was 99.9 percent pure. Its diffraction pattern showed that it contained both the α- and the β-forms. The following phases at room temperature (about 25°C) were identified: (1) solid solution of beryllium in gold, (2) Au_3Be, (3) Au_2Be, (4) AuBe, (5) $AuBe_3$, (6) $AuBe_5$, and (7) solid solution of gold in beryllium. Solubility limits of solid solutions, crystalline structure, lattice parameters, volume of unit cell, number of molecules per unit cell, and density of each intermediate phase were determined. Numerical values of above factors will be presented and discussed.

* Supported in part by ONR.

L6. New Ferroelectric Crystals. B. T. MATTHIAS, ELIZABETH A. WOOD, AND A. N. HOLDEN, *Bell Telephone Laboratories.*—In ABO_3 compounds having the perovskite structure, ferroelectric effects occur when the radius ratio A/B lies between 1.9 and 2.1, and at the same time the electronic core of the B ion has a closed shell configuration. Potassium and sodium metacolumbate, as well as potassium and sodium metatantalate, were found to be ferroelectric. Below their Curie points they go through one or more polymorphic transitions which change their domain structure. The dielectric constants are high and the crystals are piezoelectric. Approximate values for the Curie points are as follows: $KCbO_3$ ~325°C, $NaCbO_3$~425°C, $KTaO_3$~275°C, $NaTaO_3$~475°C.

L7. Thermomagnetic Investigations of Promoted Iron Oxide and Iron Catalysts. LOUIS R. MAXWELL, *The Naval Ordnance Laboratory* AND STEPHEN BRUNAUER, *Bureau of Ordnance.*—The Curie point and the intensity of magnetization of certain singly and doubly promoted iron oxide catalysts have been determined using an experimental arrangement similar to that developed by P. DeJean.[1] The singly promoted systems studied were Fe_3O_4 containing small amounts of one of the following: Li_2O, Na_2O, K_2O, Cs_2O, CaO, BaO, B_2O_3, Al_2O_3 and SiO_2. For these materials, the Curie point was found to be practically the same as for pure Fe_3O_4. One catalyst showed nearly a 50 percent reduction in intensity of magnetization by the addition of 1.7 percent BaO (by weight). The doubly promoted systems contained additions to Fe_3O_4 of Al_2O_3 and one of the following (in small amounts): Li_2O, Na_2O, K_2O, MgO, CaO, BaO, and SiO_2. The Curie point for these materials varied only slightly and was either equal to or less than that for pure Fe_3O_4. Large reductions in the intensity of magnetization were observed. Measurements on some of these materials, made after reduction in hydrogen, showed that they behaved magnetically the same as pure iron.

[1] P. DeJean, Ann d. Physik. **18**, 171 (1922). Calibration measurements of the intensity of magnetization for this apparatus were furnished by Dr. R. L. Sanford, National Bureau of Standards.

L8. Magnetic Properties of Ferromagnetic Ferrite. HAIG P. ISKENDERIAN, *Federal Telecommunication Laboratories.*—The breakdown of permeability of ferroxcube III ferrite cores (developed by Philips of Eindhoven) above 1 Mc was recently attributed* to a resonance phenomenon which is a function of the linear dimensions of the core and, therefore, it was claimed, not due to a true resonance of domains, as formerly reported.** Incremental permeability and core loss measurements made at this laboratory on ferroxcube III sample rings, give further evidence of this "resonance" effect being a function of the core dimensions; however, it is revealed that breakdown of permeability is also due to magnetic resonance effects. Peaks of permeability and core losses are obtained at frequencies of 5 to 30 Mc, for specific polarizing fields, the

peaks becoming broader for increasing frequencies. An interpretation of these peaks is that, for a given increment in polarizing field, there is a corresponding change in permeability, hence of effective length of path to electromagnetic waves, and of resonant frequency. After allowing for skin effect, the magnitudes of the permeabilities for all of these peaks are smaller than the low frequency (1 Kc) values, for the same polarizing fields. This additional loss of permeability appears to be due to internal magnetic resonance effects.

* (I) F. G. Brockman, P. H. Dowling and W. G. Steneck; (II) P. H. Dowling and F. G. Brockman, Bull. Am. Phys. Soc. **24**, No. 1, 25 (1949).
** L. Snoek, Physica **14**, 207–217 (1948).

L9. A Series Expansion at High Temperatures for the Partition Function of the Three-Dimensional Ferromagnet. D. TER HAAR, *Purdue University.*—Using Opechowski's method,[1] a series in decreasing powers of T has been calculated for the partition function of the three dimensional ferromagnet. The symmetry of the crystal is supposed to be simple cubic. If the coupling constant is denoted[2] by J and $K=J/2kT$, the partition function λ is given by the series

$$\lambda=2\left[1+\frac{3}{2}K^2+\frac{31}{8}K^4+\frac{4501}{240}K^6+\cdots\right].$$

This series can be used to compare various approximation methods in the same way as was done for the two-dimensional ferromagnet by Kramers and Wannier.[2]

[1] W. Opechowski, Physica **4**, 181 (1937).
[2] H. A. Kramers, G. H. Wannier, Phys. Rev. **60**, 252 (1941).

L10. The Permanency of Magnetism in Sedimentary Rocks. JOHN W. GRAHAM, *Carnegie Institution of Washington.*—In order to investigate the permanency of magnetism in sedimentary rocks, observations have been made of the directions of remanent magnetization in beds that were deformed or folded at remote times. The magnetic moments of these samples range from 10^{-6} to 10^{-4} c.g.s. units/cc. In a 25-million year-old conglomerate, composed largely of small slabs of fine grained sedimentary rocks, the directions of magnetizations of the various slabs are greatly scattered, in accordance with the random attitude of the slabs in the conglomerate. The flat lying undisturbed source beds of these slabs are in contrast homogeneously polarized, apparently as a result of primary sedimentation processes. The polarizations in a fine grained ferruginous sandstone bed 350 million years old that was severely folded 200 million years ago, make angles with one another throughout the fold of as much as 127 degrees. When the variously inclined beds of the fold are graphically reconstructed to lie flat once again, the widely divergent polarizations become parallel within ± 10 degrees. This is regarded as evidence that as the bed was folded, the directions of magnetization were inclined in the same way as the bed at each point in the fold, and that since the time of the folding, the directions of magnetization have not altered. Similar findings in other studies make it appear that an unchanging remanent magnetism in sedimentary rocks is not unusual.

L11. Gyromagnetic Ratios and Splitting Factors of Ferromagnetic Substances. CHARLES KITTEL, *Bell Telephone Laboratories.*—A ferromagnetic resonance experiment determines the spectroscopic splitting factor g from $h\nu=g\mu_B H_{eff}$, whereas a gyromagnetic experiment determines the magnetomechanical factor g' from $eg'/2mc=$(magnetic moment)/(angular momentum). For a central field of force $g=g'$. An atom in a solid is subjected to non-central forces from neighboring atoms, and it is observed experimentally in ferromagnetic substances that g is usually greater than two ($g\sim 2.2$), whereas g' is usually less than two ($g'\sim 1.9$). Similar behavior was discussed for paramagnetic salts of the iron group by Gorter and Kahn, who evaluated g from the ratio of the measured susceptibility to the spin-only susceptibility. A simple example for which $g\neq g'$ is furnished by Ni^{++} in a suitable cubic electric field. The ground state of the free ion is ^3F; in the crystal the ground state wave function is $(\psi_2-\psi_{-2})S_1$ in the zero approximation, and the orbital factor is nonmagnetic. With spin-orbit coupling the essential terms in the ground state function are $[(1+\epsilon)\psi_2-(1-\epsilon)\psi_{-2})]S_1$ from coupling with the higher state $(\psi_2+\psi_{-2})S_1$; here $\epsilon=-\lambda/\delta$. The orbital factor is now partly magnetic, so that $g\leqq 2+4\epsilon$; $g'\leqq 2-4\epsilon$. For Ni^{++} salts $g\leqq 2.25$, whence $\epsilon=0.06$, and we would expect $g'\leqq 1.75$.

L12. Hall Effect in Ferromagnetics. I. EMERSON M. PUGH, *Carnegie Institute of Technology.*—Early experiments[1] with ferromagnetic materials below saturation indicate that the Hall e.m.f. is proportional to the intensity of magnetization M rather than to the magnetic field H as in non-magnetic materials. Because of demagnetizing effects in the early experiments the values of H in the interior of the samples were always so small that effects proportional to H could not be detected. The measured Hall potential difference e_h could be written $e_h=kiMb$ where k is constant, i is the current density and b is the distance between the Hall probes measured perpendicular to both the current density and the intensity of magnetization. It is shown that this result is consistent with the assumption that the Hall potential gradient $\mathbf{E}_h$ in each of the domains of the ferromagnetic material is given by the vector equation $\mathbf{E}_h=k\mathbf{i}\times\mathbf{M}$. This relation is valid when $\mathbf{M}$ varies from domain to domain either in direction or magnitude or in both.

[1] A. Kundt, Wied. Ann. **40**, 257 (1893); Emerson M. Pugh, Phys. Rev. **36**, 1503 (1930); E. M. Pugh and T. W. Lippert, Phys. Rev. **42**, 709 (1932).

L13. Hall Effect in Nickel. II. ALBERT I. SCHINDLER AND EMERSON M. PUGH, *Carnegie Institute of Technology.*—Experiments in commercially pure nickel at fields well above saturation have shown that the Hall e.m.f. follows the equation

$$e_h=Ri(H+\alpha 4\pi M)b$$

and are consistent with a Hall electric field $\mathbf{E}_h$ of $\mathbf{E}_h=Ri\times(\mathbf{H}+\alpha 4\pi\mathbf{M})$ where R and α are constants of the material If R is taken to be $1/nec$ as in non-magnetic metals, n is found to be 8.8×10^{22}, that is, 1.0 ± 0.2 conduction electrons per atom. This result is close to the theoretical value of 0.6 conduction electron per atom. If the average magnetic field experienced by the conduction electrons were equal to the magnetic induction B, then α should be equal to unity. However, the experiments show that α is equal to 12 ± 2. This appears to indicate that the average magnetic field experienced by conduction electrons in a ferromagnetic material is very much higher than B.

FRIDAY MORNING AT 10:00

Department of Interior Auditorium

(I. I. RABI presiding)

Symposium on Selected Topics in Nuclear Physics

N1. Scattering of Neutrons and Protons and the Range of Nuclear Forces. H. A. BETHE, *Cornell University.* (25 min.)

N2. Proton-Proton Scattering. R. G. HERB, *University of Wisconsin.* (25 min.)

N3. Scattering of Protons by Helium 4. C. L. CRITCHFIELD, *University of Minnesota.* (20 min.)

N4. Interpretation of Recent Experiments with Protons on Lithium. R. F. CHRISTY, *California Institute of Technology.* (25 min.)

N5. Gamma-Ray Spectroscopy. THOMAS LAURITSEN, *California Institute of Technology.* (30 min.)

FRIDAY AFTERNOON AT 2:15

Department of Interior Auditorium

(L. W. ALVAREZ presiding)

Conclusion of the Symposium on Selected Topics of Nuclear Physics

O1. Recent Results with the Slow-Neutron Spectrometer at Columbia University. L. J. RAINWATER, *Columbia University.* (25 min.)

O2. Recent Progress in the Understanding of Beta-Ray Disintegration. E. P. WIGNER, *Princeton University.* (30 min.)

O3. Radioactivity of Carbon 10 and Oxygen 14. M. G. WHITE, RUBBY SHERR, AND HERBERT MUETHER, *Princeton University.* (15 min.)

O4. A Survey of the Energy-Levels of Radioactive Nuclei. A. C. G. MITCHELL, *Indiana University.* (25 min.)

O5. Deep Energy Levels in Nuclei from Neon to Calcium. E. C. POLLARD, *Yale University.* (20 min.)

FRIDAY AFTERNOON AT 2:15

East Building, National Bureau of Standards

(R. S. MULLIKEN presiding)

Molecular Spectroscopy

P1. Theoretical Computation of Transition Probabilities for Electronic Spectra of C_2 and N_2^+. HARRISON SHULL AND R. S. MULLIKEN, *University of Chicago.*—The oscillator strengths for the transitions $^3\Pi_g \leftrightarrow {}^3\Pi_u$ (Swan bands) and $^1\Pi_g \leftrightarrow {}^1\Pi_u$ of C_2 and $^2\Sigma_u^+ \leftrightarrow {}^2\Sigma_g^+$ (1st negative bands) of N_2^+ have been computed. To a good approximation, correct results are obtained by treating the above transitions as one-electron transitions, $x\sigma_g \leftrightarrow y\sigma_u$. The *MO*'s are taken as linear combinations of Slater *AO*'s, with $x\sigma_g$ and $y\sigma_u$ of the forms $x\sigma_a + x\sigma_b$ and $y\sigma_a - y\sigma_b$, respectively. Here $x\sigma$ is intermediate between pure $2p\sigma$ and the digonal hybrid *AO*, $(2s+2p\sigma)/\sqrt{2}$, and $y\sigma$ is between pure $2s$ and this digonal hybrid. For C_2, $^3\Pi_g \leftarrow {}^3\Pi_u$, the f number for the extreme case of both $x\sigma$ and $y\sigma$ digonal is 0.27; for the extreme case of $x\sigma$ as pure $2p\sigma$ and $y\sigma$ pure $2s$, 0.0063; for the intermediate case $x\sigma$ 70 percent $2p\sigma$ and 30 percent $2s$ and $y\sigma$ 70 percent $2s$ and 30 percent $2p\sigma$, 0.20. Experimental evidence indicates that hybridization is strong. Experience with other similar cases indicates that the computed result, if multiplied by a factor of $\frac{3}{2}$ or $\frac{1}{2}$, may be expected to agree well with experiment.

P2. The Infra-Red Absorption Spectra of Seven Freons. EARLE K. PLYLER, *National Bureau of Standards.*—The infrared absorption spectra of CH_2F_2, CF_4, $CClF_3$, $CHClF_2$, $CHCl_2F$, CCl_2F_2 and CCl_3F have been measured. The two active fundamentals of CF_4 were observed at 630 and 1277 cm^{-1} and 17 additional bands of low intensity were observed between 3 and 10μ. Twenty bands were found in the absorption spectra of CCl_3F. Five of the six fundamentals have been identified and the first harmonic of the sixth has been observed at 20.2μ. The other bands of CCl_3F have been classified. These spectra have been compared with other substituted methanes not containing fluorine. The C—F binding force is greater than the force between the other halogens and carbon. The two long wave-length bands of CF_2Cl_2, which should appear between 30 and 40μ, were not observed. Twenty-eight bands were ob-

served in the region below 25μ, six of which have been classified as fundamentals. The compounds were measured in the vapor state with 5 and 10 cm cell lengths.

P3. Fluorescence Studies on Some Mono-Substituted Benzenes in the Near Ultraviolet.* ARNOLD M. BASS AND H. SPONER, *Duke University.*—Fluorescence has been studied in the near ultraviolet for several benzene mono-derivatives in the vapor state. The fluorescence was excited at vapor pressures of about 10–20 mm Hg using in most cases light from condensed sparks. The spark electrodes were selected so that the excitation of the molecules by the light was mainly into the strong absorption region near the 0,0 band. This was achieved by choosing suitable strong spark lines in conjunction with short wave cut-off filters. The spectra were photographed in a medium Bausch and Lomb quartz spectrograph. The compounds studied are fluorobenzene, toluene, benzonitrile, and chlorobenzene. Except for chlorobenzene which showed no fluorescence each of the compounds was found to give a discrete band spectrum in the region 2600–3000A. The number of bands observed ranged from 65 in the fluorobenzene spectrum to about 125 in benzonitrile. Comparison of the fluorescence with the absorption spectrum shows that the two spectra are identical in the region of overlap. Analysis shows that carbon ring vibrations and hydrogen vibrations appear excited in the fluorescence spectrum. Several progressions of symmetric vibrations are identified. Other bands are explained as resulting from combinations of fundamental vibrations. Symmetry assignments are discussed for some vibrations.

* This work was supported by ONR.

P4. Remarks on the Low Lying Singlet Electronic Levels in Naphthalene.* GERTRUD P. NORDHEIM AND H. SPONER, *Duke University.*—Calculations of the electronic terms of naphthalene lead to a different succession of levels depending on the theoretical approach. The *HLSP* method (Blumenfeld) gives a moment in the long molecular axis for the transition from the symmetrical ground state to the lowest allowed excited state, and a moment along the short axis for the next allowed transition. The order of the two transitions is reversed where the *MO* method is used (German, Coulson, Simpson). The latter result is also obtained with Platt's modified free electron model. Calculations using the *HLSP* method give in addition an excited symmetric level presumably lower than the first allowed level. The near ultraviolet absorption spectrum of naphthalene originally described by Henri and de Laszlo as one system exhibits two regions of different patterns, and oscillator strengths in the ratio 1:15. This suggests two separate electronic transitions. An attempt is made to decide between the different theoretical level schemes from an analysis of the spectrum using experimental data obtained for the vapor, the solid, and for liquid and rigid glass solutions in absorption and fluorescence (Henri, Prikhotjko, Kasha). Serious difficulties will be pointed out when trying to reconcile existent experimental data with either theoretical level scheme.

* This work was supported by ONR.

P5. The Infra-Red Absorption Spectrum of Diborane. W. E. ANDERSON* AND E. F. BARKER, *University of Michigan.*—The infra-red absorption spectrum of diborane has been examined under high resolution from 3.7μ to 31μ with automatic recording grating spectrometers. The rotational fine structure in two bands of each of the three types characteristic of asymmetric top molecules has been measured. All results and observations are consistent with the conclusion that diborane has the bridge structure, and belongs to the same symmetry point group, V_h, as ethylene. The observation and structure of the band with center at 368.7 cm^{-1} provides spectroscopic evidence that the molecule is non-planar, and makes more definite the assignment of fundamental frequencies. Data on all bands fit quite well the symmetric top approximation, since accidentally two principal moments of inertia are approximately the same. Type A bands with centers at 2519.5 cm^{-1} and 1173.8 cm^{-1} yield the value of 0.582 cm^{-1} for rotational constant B, which is proportional to the average of the reciprocals of the two larger effective moments of inertia. From the type B band at 2608.6 cm^{-1} and the type C band at 972.7 cm^{-1} the values obtained for rotational constant $(A-B)$ are 2.081 and 2.079 cm^{-1} respectively, where A is inversely proportional to the minimum effective moment of inertia.

* Now at The Citadel, Charleston, S. C.

P6. The Forces Between Ammonia Molecules. VERNON MYERS, *Pennsylvania State College.*—The long range attractive forces between ammonia molecules were calculated from the known dipole moment and optical dispersion data. The short range repulsive forces were approximated by a hard sphere model. The molecular diameter was determined from a comparison of the experimental and calculated second virial coefficients. The differences between the computed and observed virial coefficients varied from -13 percent at 300°K to 10 percent at 600°K for a molecular diameter of 3.16A.

P7. Characteristics of the Untuned Cavity Microwave Spectroscope.* I. R. WEINGARTEN** AND G. E. KIMBALL, *Columbia University.*—The successful use of bolometers to measuer transient as well as steady state energy density in an untuned cavity has been reported. It has also been reported that Lamb's formula for radiation loss through a window was verified using bolometers to observe decay transients.[1] Lamb also predicted the dependence of energy sampling on the number of excited modes in the cavity and the total length of detectors. These results have been investigated for cavities with thermocouple and bolometer detectors. The sampling fluctuation is found to decrease inversely as the square root of the number of detectors and excited modes. It is also shown that the signal sensitivity is proportional to the total length of bolometer detectors. The practical limitations determining signal as well as absorption sensitivity are considered in their influence on the design of a working spectrometer. A method is also presented and analyzed for using a small sampling cell in the larger cavity, when making measurements on strongly absorbing gases.

* Work supported by the Signal Corps and ONR.
** Present address: Taller and Cooper Inc., Brooklyn, N. Y.
[1] Weingarten and Kimball, Bull. Am. Phys. Soc. 24, No. 1, 58 (1949).

P8. Spectroscopy between 1.5 and 2 mm. Wave-Length Using Magnetron Harmonics.* J. H. N. LOUBSER** AND C. H. TOWNES, *Columbia University.*—Magnetrons of fundamental wave-length 1 cm or less generate enough harmonic power to allow spectroscopic work to wave-lengths at least as short as 1.5 mm.[1] The ratio of power between fundamental, 2nd, 3rd, 4th, and 5th harmonic is 10^{10}:4000:20:4:1 in a typical case. Harmonic outputs of magnetrons vary greatly, however, with operating conditions, impedance match, and with magnetron design. A Golay cell was used and found to be a satisfactory detector for wave-lengths in the millimeter range, where it was approximately as sensitive as in the infra-red region. Absorption due to the lowest frequency rotational transition of the molecule $D\ I$ was observed at 1.55 mm wave-length. Absorption due to the NH_3 inversion spectrum at 12 mm was measured as a function of wave-length between 6 mm and 2 mm with pressures of one atmosphere and less. The measurements agree reasonably well with the Van Vleck–Weisskopf line shape, being approximately constant between 6 mm and 2 mm wave-length.

* Work supported jointly by the Signal Corps and ONR.
** Carbide and Carbon post-doctoral fellow in physics.
[1] We have benefitted from discussions with Professors J. H. Rohrbaugh and J. H. Greig who first detected magnetron harmonics in the millimeter range.

P9. Microwave Rotational Spectrum of $CH_2=CF_2$.* A. ROBERTS AND W. F. EDGELL, *State University of Iowa.*—Over eighty lines in the spectrum of CH_2CF_2 have been observed, mainly between 21,000 and 29,000 mc. Fifteen lines have been identified, with the assistance of Stark effect measurements. The analysis yields the following molecular constants:

$a = 11{,}001.8 \pm 1$ mc
$b = 10{,}428.5 \pm 1$ mc
$c = 5345.6 \pm 1$ mc
$K = +0.7973 \pm 0.0001$
$\mu = 1.366 \pm 0.02$ debye

Present data are consistent with the following assumed parameters, although some modification is to be expected from the analysis of isotopic molecules:

C–F = 1.32 A° FCF angle = 110°
C=C = 1.31 A° HCH angle = 110°
C–H = 1.07 A°

Lines which are tentatively ascribed to $C^{13}F_2CH_2$ have been observed; an analysis is in progress.

* This research was supported in part by ONR.

P10. Microwave Spectra of Nitrous Oxide. D. K. COLES AND R. H. HUGHES, *Westinghouse Research Laboratories.*—The rotational transition $J=0$ to $J=1$ of the N_2O molecule has been observed for all different combinations of the N^{14} and N^{15} isotopes. Rotational frequencies are listed below in megacycles per second:

$N^{15}N^{15}O^{16}$—24,274.78
$N^{15}N^{14}O^{16}$—24,274.60
$N^{14}N^{15}O^{16}$—25,121.55
$N^{14}N^{14}O^{16}$—25,123.25.

It is noteworthy that the heaviest isotopic species, $N^{15}N^{15}O^{16}$, actually has a smaller effective moment of inertia than the lighter species $N^{15}N^{14}O^{16}$. This anomaly can be explained as an effect of the isotopic substitution on the zero-point vibration of the molecule, which in turn influences the average moment of inertia. Internuclear distances, as calculated from the several rotational frequencies above, differ among themselves by as much as 0.02A. Measurements of line width and Stark effect give an intermolecular collision cross section of 87A² and a dipole moment of 0.34 debye units.

P11. Dispersion in NH_3 in the Microwave Region. GEORGE BIRNBAUM, *National Bureau of Standards.*—When certain analytic conditions are satisfied by the complex dielectric constant, $\epsilon=\epsilon'-i\epsilon''$, its behavior is completely determined if either ϵ' or ϵ'' is specified over the entire frequency range.[1] Using ϵ given by Van Vleck and Weisskopf for collision broadened lines, the absorption equation where $\alpha=2\pi\nu\epsilon''$ cm^{-1} is fitted to data on the absorption of microwaves by ammonia,[2] from $\nu=0.31-1.2$ cm^{-1}, at pressures of 10, 30, and 76 cm Hg. The behavior of ϵ' due to this absorption is computed by using the values for the line widths and resonant frequencies obtained from the curve fitting. The contribution of the microwave absorption to the static value of ϵ' is calculated from the integrated line intensity by $\epsilon'(0)-1=1/\pi^2\int_0^\infty(\alpha d\nu/\nu^2)$. Computed dispersion curves are found to be in agreement with data obtained on the variation of ϵ' with pressure,[3,*] up to 76 cm Hg at 0.093 and 0.31 cm^{-1}.

[1] J. H. Van Vleck, Radiation Laboratory Report No. 735.
[2] I. R. Weingarten, Columbia Radiation Lab. Rpt. May 1, 1948.
[3] H. Lyons, G. Birnbaum, and S. J. Kryder, Phys. Rev. **74**, 1210A (1948).
* This work was part of a thesis presented for the M.S. degree at George Washington University.

FRIDAY AFTERNOON AT 2:15

Department of Commerce

(LLOYD SMITH presiding)

Solid-State Physics, Mostly Semi-Conductors

Q1. Sensitized Luminescence of Alkali-Halide Phosphors. J. H. SCHULMAN, E. BURSTEIN, R. J. GINTHER, M. WHITE, AND L. W. EVANS,* *Naval Research Laboratory.*—NaCl:(Pb+Mn) phosphors, precipitated from NaCl–$MnCl_2$–$PbCl_2$ solutions by HCl, exhibit orange emission under 2300–3200A excitation. NaCl:Mn prepared by this procedure is substantially non-absorbing and non-luminescent upon irradiation with light of wave-length greater than 2200A. NaCl:Pb has a sharp absorption and excitation band at 2730A, resulting in weak, near ultraviolet luminescence. NaCl:(Pb+Mn) also shows an absorption band peaking at 2730A, but in some preparations an additional absorption peak is observed at 2590A. Excitation peaks at 2730A and 2590A are found for the orange emission of the NaCl:(Pb+Mn) phosphors, even when a resolved 2590A absorption peak is not observable. The ultraviolet emission from NaCl:(Pb+Mn) is considerably weaker than that from NaCl:Pb. The data indicate that NaCl:(Pb+Mn) is a sensitized luminescent system. Preliminary observations indicate the occurrence of sensitized luminescence in other manganese-activated alkali halide phosphors. Heating of precipitated NaCl:(Pb+Mn) irreversibly destroys the 2590A excitation peak, leaving only the 2730A band. This indicates that the precipitated phosphor contains an unstable and a stable configuration of activator and sensitizer. Some suggestions concerning the nature of the different configurations are discussed.

* Present address: Sylvania Electric Products, Inc., Emporium, Pennsylvania.

Q2. On the Structure of the Barrier Layer in Dry Disk Rectifiers. K. LEHOVEC, *Signal Corps Engineering Laboratories.*—Impedance measurements on dry disk rectifiers at different frequencies are interpreted in terms of a "resistivity" distribution within the barrier layer. If a small a.c. voltage is superimposed on a d.c. bias, the following data can be obtained from the resistivity curve (which changes with the d.c. bias): (a) the distribution of the local field intensity within the barrier layer, (b) the corresponding distribution of the space charge variations, and (c) the change of the local space charge density with the d.c. bias. Measurements on selenium rectifiers indicate that the change of space charge density with d.c. bias spreads over a considerable part of the barrier layer, which, therefore, is not an exhaustion layer with immobile impurities. Illustrative curves are presented.

Q3. Calculations of the Energy Levels in Elemental Silicon. D. K. HOLMES.—Bloch-type wave functions of zero wave number are formed by use of the cellular method in combination with group theory. These yield the energies of the states at the top of the filled band and at the bottom of the empty band, if it is assumed that these states are associated with zero wave number. The calculated energy gap between the two bands varies from 10 to 5 electron volts as the internuclear spacing changes from 4.44 to 5.50 Bohr radii. (This work resembles previous calculations by G. E. Kimball and J. F. Mullaney.) The effective electron mass associated with the empty band is calculated by performing numerical integrations over the unit

cell of the zero wave number functions determined above and perturbing functions. This electron mass is found to vary from 0.22 to 0.16 that of the free electron mass over the same range of internuclear separations as above. The work is being extended to wave numbers on the surface of the Brillouin zone.

Q4. Some Observations on the Photoeffect in Cadmium Sulphide. A. Rose, P. K. Weimer and S. V. Forgue, *RCA Laboratories Division.*—Exceedingly high photo-currents have been reported for pure, single crystals of cadmium sulphide.[1] Models for this, as well as other photoconductors showing a secondary photoeffect, have been presented[2] in which electrons from the metal electrodes travel the full inter-electrode distance. Their transit is permitted by the action of light in reducing space charge and/or filling electron traps. In contrast to the above, we have found similarly high photo-currents in polycrystalline samples of cadmium sulphide and in samples that have been baked in oxygen. Since it is improbable that the metal electrons traveled the full interelectrode distance (of the order of millimeters), a model for the secondary photoeffect is suggested which makes use of multiple thin insulating barriers separating relatively conducting portions of the crystal. The barriers may be opened up by light to permit the passage of many electrons per absorbed quantum. Some further tests on "single" needle-like crystals of cadmium sulphide are not inconsistent with the above picture.

[1] R. Frerichs, Phys. Rev. **72**, 594–601 (1947).
[2] R. Frerichs and A. J. F. Siegert, Phys. Rev. **74**, 1875 (1948); A. von Hippel, J. Chem. Phys. **14**, 370–378 (1946).

Q5. Photoconductivity of Indium Selenide.* Donald Bode and Henry Levinstein, *Syracuse University.*—The photoconductive properties of indium selenide have been investigated. The films were prepared by two methods. The first consists of direct evaporation of indium selenide in a high vacuum. The second consists of evaporation of successive layers of indium and selenium, accompanied by continuous heating of the film. After evaporation, films formed by the first method show slight sensitivity which may be increased by baking in a high vacuum at about 200 degrees centigrade. Films formed by the second method need no further heat treatment. White light sensitivity of the order of magnitude of commercial lead sulfide cells has been obtained. The long wave-length sensitivity limit of these films is about 2 microns. Their resistance for a film area of 2.5×0.2 cm varies between 10^3 and 10^7 ohms, depending upon film composition and thickness. The films may be exposed to air continuously, and they generally show an increase in sensitivity with age. Since no oxygen treatment is necessary to sensitize the layers, the analysis of the photoconductive mechanism may be simplified.

* This work is supported by the Air Force.

Q6. Photoconductivity and Optical Absorption in BaO Crystals.* Winfield W. Tyler, *Cornell University.*—Measurements on single crystals of BaO[1] indicate that photoconductivity begins at about 3300A, rises rapidly in the region from 3300A to 3100A, then rises slowly to a maximum at about 2300A. Measurements were made at room temperature on crystals about $\frac{1}{2}$ mm$\times\frac{1}{2}$ mm$\times1$ mm in size. Currents observed are secondary in nature, rising exponentially to approximate equilibrium values after two minutes exposure to radiation. Complete recovery of the crystal after exposure takes about twenty minutes. This behavior differs from photoconductivity in ZnS and diamond in the same spectral region. In these crystals, equilibrium conditions are obtained almost immediately after exposure or removal of radiation. Measurements of the transmittance of clear crystals of BaO indicate strong absorption starting at about 3300A. At 3150A the absorption constant is about 30 mm^{-1}. The crystals studied were several tenths of a mm in thickness and no transmission was detected in the region from 3100A to 2000A. Any fine structure in this region will have to be observed using much thinner specimens or evaporated films.

* Supported in part by ONR.
[1] R. L. Sproull, Bull. Am. Phys. Soc. **24**, 17 (1949).

Q7. The Mobility of Electrons in Diamond.* C. C. Klick** and R. J. Maurer, *Carnegie Institute of Technology.*—The mobility of photoelectrons in diamond has been determined between room temperature and 100°K by measurement of the Hall effect. The photoelectrons were produced in a Type I diamond by absorption of radiation of wave-length greater than 3000A. The effect of polarization has been included in the calculation of the Hall potentials. In interpreting the data, the mobility of the holes has been assumed to be negligible. At room temperature the mobility is 900 cm^2/volt-sec., a factor of six larger than indicated by the theory of Seitz.[1] In agreement with this theory, the mobility is inversely proportional to the three halves power of the absolute temperature. The temperature dependence of the photocurrent was found to vary with the wave-length of the exciting radiation. Wave-lengths below 3000A could not be used in the mobility determinations because the resulting photocurrents yielded unsymmetrical Hall potentials.

* This work was partially supported by ONR.
** Westinghouse Fellow in Physics. Now at the Naval Research Laboratory, Washington, D. C.
[1] F. Seitz, Phys. Rev. **73**, 549 (1948).

Q8. Pressure Coefficient of Resistance in Intrinsic Semiconductors.* P. H. Miller, Jr., and Julius Taylor, *University of Pennsylvania.*—The energy gap in intrinsic semiconductors depends on the interatomic distance, the calculation of Mullaney[1] indicating a fractional increase of gap energy of about 10 times the volume strain. In silicon where the separation of the filled and conduction bands is about 1.1 ev, the fractional increase resistance at 300°C should be approximately 100 times the volume strain or 3×10^{-5} times the hydrostatic pressure in atmospheres. We have measured an increase in resistance in germanium (a semiconductor similar to silicon) with application of hydrostatic pressure at 135°C. This is the temperature at which the maximum in the resistivity occurs. Measurements were made at this temperature since the effect of variation of temperature on resistivity are minimized. By making estimates of the ratio of the number of intrinsic electrons to the number of impurity electrons, we obtain a preliminary value of the isothermal pressure coefficient of resistance of pure germanium at 135° of 4×10^{-6} per atmosphere. Thermodynamic considerations indicate that the adiabatic coefficients may be smaller by one quarter.

* This work was supported by Bureau of Ships, U. S. Navy.
[1] J. F. Mullaney, Phys. Rev. **66**, 326 (1944).

Q9. Electron and Hole Mobilities in Germanium Single Crystals. G. L. Pearson, *Bell Telephone Laboratories.*—Electrical resistivity and Hall measurements have been made on single crystals[1] of high purity germanium (both n-type and p-type). At ambient temperature, the resistivities of these samples were approximately 10 and 0.6 ohm-cm. In the high temperature region where lattice scattering predominates the electron, and hole mobilities are given by the relation $\mu_e=1.5\mu_h=1.35\times10^7T^{-1}$ cm^2/volt-sec. These mobilities which amount to 2600 and 1700 cm^2/volt-sec., respectively, at 300°K are considerably higher than previous values[2] reported for multicrystalline samples. The ratio of 1.5 for electron to hole mobility at any given temperature is considerably smaller than the previously reported value,[2] and indicates a mass ratio of $m_h/m_e=(\mu_e/\mu_h)^{2/5}=1.18$ for germanium.

[1] The germanium was prepared by H. C. Theuerer of the Bell Telephone Laboratories.
[2] Torrey and Whitmer, *Crystal Rectifiers*, p. 63.

Q10. Current Flow across $n-p$ Junctions. W. Shockley, G. L. Pearson, and M. Sparks, *Bell Telephone Laboratories.*—

In silicon or germanium samples containing varying donor and acceptor concentrations, a conversion from n-type to p-type may occur producing an $n-p$ junction. For some samples the transition region, where there is appreciable space charge, is small compared to the diffusion distance of holes or electrons in the material of the other type. For this reason, the forward current flowing across an $n-p$ junction will have an appreciable hole component on the n-type side and vice versa. However, if the material on one side has much higher conductivity, the current will be primarily of carriers of its type. Evidence for flow of carriers across the junction is furnished by studies of impedance as a function of frequency which show an admittance of the form $(if)^{\frac{1}{2}}$, characteristic of diffusion. The presence of holes injected into n-type material has been shown by transistor action on a collector point. The rectification characteristic of several junctions has been found to follow the theoretical curve $I \propto 1-\exp(\alpha eV/kT)$ with $\alpha=1$ as predicted by the theory discussed. If the transition region is wide compared to the diffusion length, a junction of low resistance is obtained in germanium, in keeping with the low intrinsic resistivity at room temperature.

Q11. Concentration of Holes and Electrons by Magnetic Fields. H. SUHL AND W. SHOCKLEY, *Bell Telephone Laboratories.*—Using a small rod of n-type germanium 0.013×0.013 cm in cross section with a longitudinal electric field of about 30 volts cm and transverse magnetic fields up to 20,000 gauss, we have obtained data indicating that holes injected into the rod by an emitter point have been concentrated into a layer less than 0.002-cm thick on one side of the filament. Hole concentrations at the surface have been deduced from changes in resistance of a probe point contact. The results have been interpreted quantitatively and show that injected holes decay chiefly by recombination on the walls; the recombination coefficient has the dimensions of velocity and is about 1500 cm/sec. The increased rate of recombination occurring when the holes are concentrated against a surface can account for large apparent magnetoresistance effects observed under conditions of hole injection. Quantitative data on this effect will permit evaluating experimentally both surface and volume recombination coefficients. We are indebted to G. L. Pearson and J. R. Haynes for suggestions and help with germanium filaments.

FRIDAY AFTERNOON AT 2:15

Departmental Auditorium

(D. H. EWING presiding)

Electron Optics

Invited Paper

R1. Field Mapping by Electron-Optical Methods. L. MARTON, *National Bureau of Standards.* (30 min.)

Contributed Papers

R2. Improved Baffle System for Helical Focusing β-Ray Spectrometer. L. FELDMAN AND C. S. WU, *Columbia University.*—A new ring focusing baffle system for the helical focusing beta-ray spectrometer has been designed and built to take advantage of the maximum solid angle as resolution relationships recently pointed out by theoretical investigations of quadratic focusing.[1,2] The existence of the ring focusing property was originally pointed out by Witcher[3] and this principle was used in the design of the original baffle. However, to obtain best resolution for a given solid angle, the initial angle between the axis and the electron beam should be between 30° and 60°. The new baffle was designed to utilize the optimum condition in which the initial angle is between 32° and 44° as compared with the 8.9° to 18.7° angle of the original baffle. Preliminary investigations indicate a factor of five increase in transmission of the new baffle over the original baffle with the same resolution. This increase in transmission of the spectrometer is a great improvement in the investigation of beta-spectra of sources of very low specific activity.

[1] S. Frankel, Phys. Rev. **73**, 804 (1948).
[2] E. Persico, Phys. Rev. **73**, 1475 (1948).
[3] C. M. Witcher, Phys. Rev. **60**, 32 (1941).
[4] E. Haggstrom, Phys. Rev. **62**, 144 (1942); Wu, Havens, Jr., Albert, and Grimm, Phys. Rev. **73**, 1259 (1948).

R3. Magnetic Time-of-Flight Mass Spectrometer.* PAUL I. RICHARDS, EARL E. HAYS, AND S. A. GOUDSMIT, *Brookhaven National Laboratory.*—An exploratory model of the mass spectrometer proposed by one of us (S. A. Goudsmit, Phys. Rev. **74**, 622–23 (1948)) has been completed. A readily available but very unsuitable magnet with a 15-inch pole diameter and 2-inch gap provides the magnetic field of 600 to 1200 gauss. A hot tungsten foil ionizes alkali atoms evaporated from a nearby oven; these are accelerated for a fraction of a microsecond by a pulsed grid, so that different masses receive roughly the same momentum and follow similar orbits. Amplified ion current received by a shielded plate is finally displayed on a synchroscope triggered by the accelerating pulse. Results were surprisingly good for this preliminary apparatus. Although the dispersion is only about one microsecond per mass unit, accuracy of one in 10^3 near mass 100 is easily attained. The small magnet gap and necessary size of the source and detector at present, restrict the observable ion revolution to the first and second. We have started on another model in which the dispersion will be increased by allowing the ions to travel at least ten revolutions.

* Research carried out at Brookhaven National Laboratory under the auspices of the AEC.

R4. Deflection of Electrons in an Inhomogeneous Electrostatic Field. JENNY E. ROSENTHAL, *Evans Signal Laboratory.*—A mathematical method is presented for determining the deflection of an electron beam in an electrostatic field produced by two plates charged to $+V_0$ and $-V_0$, respectively. The plate system has two mutually perpendicular planes of symmetry but is otherwise arbitrary. Because of symmetry the problem can be treated in two dimensions. To determine the

potential between the plates, the given boundary is approximated by a superposition of boundaries for which Laplace's equation is solved in terms of polynomials. The equation for the deflection of an electron entering the deflecting field with a constant velocity can be solved analytically to any desired degree of approximation provided the potential giving the electron its initial velocity is large compared with the deflecting potential. The results are applied to cathode-ray tubes, in particular to the problem of minimizing spot distortion without affecting the deflection appreciably.

R5. A Microwave Linear Accelerator for Electrons. D. ERRETT, J. MACKAY, R. PEPPER, F. RIEKE, D. ROLLER, AND L. SILBER, *Purdue University.*—The accelerator employs a standing electromagnetic wave in a round wave guide loaded by circular irises. The mode of oscillation is that in which the longitudinal electric field has a node at each iris (π-mode). Power is provided by a pulsed magnetron operating at 10.6 cm. There are eighteen irises and the spacing between them has been fixed on the basis of electrons with an initial energy of 300 kev, an effective accelerating field of 10^4 volts/cm, and a final energy of 1.15 Mev. At present the accelerator is operated without magnetic focusing coils; stray magnetic fields have been reduced to less than 1/100 oersted by iron shields. The electrons are injected through a 1-mm aperture and emerge from the accelerator in a beam having a diameter of about 1.5 cm. According to preliminary measurements made with a magnetic analyzer, the major portion of the electrons have energies between 0.8 and 1.4 Mev, and there is a weak group with energies less than 300 kev.

FRIDAY AFTERNOON AT 4:30

Departmental Auditorium

(L. J. HAWORTH presiding)

Invited Papers

RA1. Recent Experimental Work at the Berkeley Radiation Laboratory. L. W. ALVAREZ, *University of California, Berkeley.* (30 min.)

RA2. Interpretation of High Energy Experiments at the Berkeley Radiation Laboratory. ROBERT SERBER, *University of California, Berkeley.* (30 min.)

SATURDAY MORNING AT 9:45

Department of Commerce

(W. E. MEGGERS presiding)

Symposium on Atomic Frequency and Time Standards

S1. Astronomical, Radioactive, and Atomic Time. GEORGE GAMOW, *George Washington University.* (20 min.)

S2. Primary Time Standards in Astronomy. G. H. CLEMENCE, *U. S. Naval Observatory.* (30 min.)

S3. The Present Status of Astronomical Time Standards. PAUL SOLLENBERGER, *U. S. Naval Observatory.* (20 min.)

S4. The Atomic Clock of the National Bureau of Standards. HAROLD LYONS, *National Bureau of Standards.* (30 min.)

S5. Ultimate Accuracy of an Atomic Clock Using Absorption Lines. C. H. TOWNES, *Columbia University and National Bureau of Standards.* (20 min.)

S6. Some Design Considerations of an Atomic Clock Using Atomic Beam Techniques. POLYCARP KUSCH, *Columbia University and National Bureau of Standards.* (20 min.)

SATURDAY MORNING AT 9:30

Departmental Auditorium

(W. H. ZINN presiding)

Nuclear Masses; Fission; Reactions of Transmutation Involving Electrons and Gamma-Rays

T1. The Neutron-Hydrogen Mass Difference. WILLIAM E. STEPHENS, *University of Pennsylvania.**—The recent measurement of the energy of the neutron hydrogen capture gamma-ray by Bell and Elliott[1] has thrown some doubt on the older values of the deuteron binding energy and the neutron hydrogen mass difference derived from it.[2] A re-examination of later and more accurate measurements of transmutation cycles (including the new Westinghouse $C^{14}(p, n)$ threshold)[3] allows an

independent calculation of the neutron hydrogen mass difference. A weighted average of several such cycles gives $n-H=774\pm16$ kev or B.E.(D)$=2207\pm16$ kev. This is larger than previous values but not inconsistent with them. It is, however, still appreciably lower than the values given by Bell and Elliott of $n-H=804\pm5$ kev and B.E.(D)$=2237\pm5$ kev. A comparison of the two $[(pn),\beta]$ cycles involving C^{14} and B^{11} gives an estimate of the neutrino mass to be -2.5 ± 10 kev.

* Supported by ONR.
[1] R. E. Bell and L. G. Elliott, Phys. Rev. **74**, 1552 L (1948).
[2] W. E. Stephens, Rev. Mod. Phys. **19**, 1 (1947).
[3] Shoupp, Jennings, and Sun, Phys. Rev. **75**, 1 (1949).

T2. Neutron-Proton Mass Difference from the D−D Reactions. A. V. TOLLESTRUP, F. A. JENKINS, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.*—Bombardment of a target of D_2O ice by deuterons leads to the reactions (1) $D(d,p)H^3$ and (2) $D(d,n)He^3$. The energies of both H^3 and He^3 have been measured by a double focusing magnetic spectrograph, using bombarding deuterons of various energies between 250 and 625 kev. The particles emerged from the target at a mean angle of 137.8° with the incident beam and were detected with a scintillation counter. By properly adjusting the inflow of D_2O vapor, a thin target of ice could be maintained on the liquid-air-cooled copper target, and under these conditions the high energy cut-offs had a slope agreeing with the known window of the magnetic spectrograph. The results are $Q_1=4.039\pm0.020$ Mev, $Q_2=3.256\pm0.016$ Mev, and $Q_1-Q_2=0.783\pm0.004$. The result for Q_2 is in reasonable agreement with the recent determination of Argo. It will be noted that the difference in the two Q's can be measured with considerably smaller absolute error than either of the individual values. The difference is a measure of the n^1-H^1 mass difference. Using $H^3-He^3=0.0169\pm0.0003$ we find $n^1-H^1=0.800\pm0.004$ neglecting the mass of the neutrino. The result is in agreement with the value 0.804 ± 0.009 obtained from the recent determination of the binding energy of the deuteron and indicates a small upper limit for the neutrino rest mass. This work was assisted by the joint program of the ONR and the AEC.

T3. Integral Ratios Between Nuclear Masses and Binding Energies. ENOS E. WITMER, *University of Pennsylvania.*—Here E ( ) means the binding energy of the isotope in parentheses and N ( ) the mass of the nucleus of the isotope in parentheses. The following numerical ratios exist, in most cases to a high degree of precision:

$N(H^1):E(N^{14})=9:1$
$E(He^3):E(H^2)=7:2$
$N(C^{13}):E(O^{16})=381:4$
$N(O^{16}):E(C^{12})=812:5$
$N(O^{16}):\{E(O^{16})-E(C^{12})\}=2929:6$
$N(He^3):E(He^3)=2209:6$
$N(S^{32}):N(H^1)=1301:41$
$E(S^{32}):E(O^{16}):E(N^{14}):E(C^{13}):E(He^3)=107:50:41:38:3$
$E(O^{16}):E(C^{13}):E(Li^7):E(He^4)=140:101:43:31$

Also others. These results lead naturally to the concept of the *prout* as a natural unit of mass for stable nuclei in the ground state, which the writer introduced before.

T4. On Fission-Asymmetry. G. C. WICK, *University of California, Berkeley.*—The asymmetry of slow-neutron fission will be discussed on the assumption that the asymmetric type of splitting requires a lower activation energy. An attempt has been made to correlate this assumption with the bends of the packing fraction curve and with the irregular changes of the nuclear radius connected with closed shells. In this way some light may be thrown on an empirical rule noticed by M. Mayer* as well as on the different behavior of fast fission.

* M. G. Mayer, Phys. Rev. **74**, 235 (1948).

T5. On the Tripartition of U^{235} Nuclei by Thermal Neutrons. LOUIS ROSEN AND ALVIN M. HUDSON.—By making use of a triple ionization chamber and a triple coincidence circuit in conjunction with either a gated ten-channel amplitude discriminator or a double coincidence circuit, it has been found possible to determine the frequency of triple fissions in U^{235} relative to the frequency of binary fissions. Neutrons from either the Los Alamos cyclotron or the Los Alamos slow neutron reactor were used to bombard a very thin foil of U^{235} mounted in the triple ionization chamber in such a way that all three chambers could see the active material. The geometry was such that each time Chamber I or Chamber III received a fission fragment, the mate of that fragment was obliged to enter Chamber II. Pulses from all three chambers were amplified and fed to the triple coincidence circuit. Whenever three pulses were received within its resolving time the amplitude of the pulse from Chamber II was utilized to determine whether the triple coincidence recorded was due to a triple fission or to two binary fissions. The results of the experiment are that triple fissions occur to the extent of 4.3 ± 2.3 per 10^6 binary fissions in the case where the three fragments come off with comparable masses.

T6. Ternary Fission in Uranium. J. T. DEWAN AND K. W. ALLEN, *Chalk River Laboratories.*—A coincidence counting method, similar in principle to that used in the study of long range α-particles produced in fission,[1] has been used to investigate short range particles ($R<1$ cm) emitted in fission. Particles with a maximum range of 8 mm of air are produced in approximately 1 percent of all fissions of uranium by slow neutrons. Their maximum initial specific ionization is about four times greater than the *maximum possible* specific ionization of α-particles. By placing thin absorbers directly over the source (<0.1 mg cm^{-2} uranium oxide enriched in U^{235}), we have shown that these particles are not recoiling nuclei produced by fission fragments in their passage through the source and counter gas. A semi empirical determination of the mass of particles with the observed specific ionization of 1.02 Mev cm^{-1} for a residual range of 6.5 mm is $M=13\pm4$. The abundance of this mode of fission and the ranges of the light particles are in good accord with the results of other observers.[2,3] No evidence has been found for the division of uranium into three particles of comparable mass.

[1] Allen and Dewan, Bull. Am. Phys. Soc. **23**, No. 7, 16 (1948).
[2] Green and Livesey, Phil. Trans. **A241**, 323 (1948).
[3] Cassels, Dainty, Feather and Green, Proc. Roy. Soc. **A191**, 428 (1947).

T7. Electron Excitation of In^{115}*. B. WALDMAN, W. C. MILLER, AND D. GIDEON, *University of Notre Dame.*—The direct electron excitation of In^{115}* has been studied from 0.8 to 2.0 Mev. The excitation curve obtained rises monotonically and is similar to the thick target x-ray excitation curve.[1] Experimental evidence will be given showing that x-rays produced by the electrons in the indium contribute very little to the excitation. The cross section for electron excitation at 1.2 Mev is of the order of 10^{-33} cm^2. This is a factor of 4 greater than the cross section for excitation by x-rays produced by electrons of the same energy incident on a thick gold target. This research has been supported by the Research Corporation and the joint program of the AEC and ONR.

[1] W. C. Miller and B. Waldman, Phys. Rev. **75**, 425 (1949).

T8. Capture Gamma-Ray Studies. H. E. KUBITSCHEK AND S. M. DANCOFF, *University of Illinois, Argonne National Laboratory.*—A beam of neutrons from the Argonne heavy water pile was used to study the gamma-rays emitted on neutron capture by various elements. The capture gamma-rays produced Compton electrons which were absorbed in aluminum between coincidence counters. From these data the maximum gamma-ray energies can be found. These agree qualitatively with the semi empirical formulas of Feenberg

and Bohr-Wheeler for neutron binding energies, but considerable fluctuations are observed in individual cases. Some features of the spectral distribution of gamma-energies in a single element could also be distinguished. The position of the intensity maximum appears to agree with the statistical theory of nuclear energy levels.[1] However, many more high energy quanta are observed than are predicted by this theory. Finally we have measured the relative yield of capture gamma-rays for various elements, a quantity essentially proportional to the total number of gamma rays emitted per neutron captured. These yields varied, for 26 target elements studied, by only ±30 percent about a mean.

[1] H. A. Bethe, Rev. Mod. Phys. **9**, 232 (1937).

T9. The Capture γ-Ray Spectrum of Cadmium. BERNARD HAMERMESH, *Argonne National Laboratory.*—Photographic plates soaked in D_2O may be used for γ-ray studies.[1] By measuring the range of the photo-protons resulting from the photo-disintegration of the deuteron, the γ-ray energies may be determined. The method is limited to γ-ray energies above 3.2 Mev. A beam of thermal neutrons was incident upon a sheet of cadmium placed near an Ilford C_2 plate soaked in D_2O. No neutrons were allowed to strike the plate. A control plate prepared in a similar fashion was used to determine tracks arising from radiation other than capture γ-rays. 56 mm² of each of the plates were searched and 301 tracks were found on the γ-ray exposed plate and 40 were found on the background plate. The data were corrected for dip of tracks into emulsion, probability of leaving emulsion, variation of (γ, n) cross section of the deuteron with energy, and difference of range of protons in wet and dry emulsions. The spectrum shows a continuous spread of energies decreasing in intensity from 3.2 Mev to a cut-off at about 7 Mev.

[1] G. Goldhaber, Phys. Rev. **74**, 1725 (1948).

T10. Angular Distribution and Relative Yields of Gamma-*n* Processes with Bremsstrahlung.* G. A. PRICE AND D. W. KERST, *University of Illinois.*—Shielding the betatron with two feet of concrete has reduced the neutron background sufficiently to allow quantitative measurements of relative neutron yields and of angular distributions from $\gamma - n$ processes. Neutrons were detected by a rhodium foil in paraffin shielded from background by paraffin and cadmium except on the side toward a sample which hung in the x-ray beam. The betatron was run at 19.7 Mev. Most of the samples were cylinders ~10 cm long, and ~2 cm diameter. The distribution of neutrons from lead was spherically symmetrical with a probable error of ±3 percent in the region from 30° to 150° from the x-ray beam. The same was true for iron within ±9 percent. The neutron intensity from deuterium was most intense at 90° and a less pronounced asymmetry was noticed with beryllium. With the apparatus it was possible to obtain the relative yields of sixteen elements very quickly. Within 50 percent the yield observed is $50.Z^2$ neutrons per mole per R from bismuth to aluminum. Beryllium and deuterium yields were about $4.\times 10^5$ neutrons per mole per R.

* Assisted by the joint program of the ONR and AEC.

T11. X-Ray Yield Curves for $(\gamma, 2n)$ and (γ, p) Reactions. G. C. BALDWIN, *General Electric Company.*—X-ray yield curves have been taken and analyzed by the method previously reported[1] for the reactions $F^{19}(\gamma, 2n)F^{17}$, $Mg^{26}(\gamma, p)Na^{25}$ and $Be^9(\gamma, p)Li^8$. The latter reaction, yielding a 0.88-second half-life, required a special technique which is now being applied to measurement of other reactions in the light elements. The resulting curves of relative cross section *vs.* quantum energy pass through maxima at 30, 28, and 27 Mev, respectively, and are more asymmetrical than corresponding curves for (γ, f) and (γ, n) reactions.

[1] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **71**, 3 (1947); Phys. Rev. **73**, 1156 (1948).

T12. Observation of 20-Mev Gamma-Rays from the $T^3(p, \gamma)He^4$ Reaction. H. V. ARGO, H. T. GITTINGS, A. HEMMENDINGER, G. A. JARVIS, H. MAYER, AND R. F. TASCHEK, *Los Alamos.*—A comparison of the absorption in aluminum of beta-rays produced by thick-target gamma-rays from the $T^3(p, \gamma)He^4$ and $Li^7(p, \gamma)Be^8$ reactions has been made using triple coincidence counters. A thick target of T^3 absorbed in a disk of zirconium[1] and an incident proton energy of 1.01 Mev was used. An estimate of total cross section for this reaction will be given.

[1] Graves, Rodriguez, Goldblatt, and Meyer, personal communication, to be published in Rev. Sci. Inst.

SATURDAY MORNING AT 9:30

National Academy

(M. L. POOL presiding)

Beta- and Gamma-Emitters, I

U1. Radioactive Sources of High Specific Activity Produced with a Betatron.* R. A. BECKER AND F. S. KIRN, *University of Illinois.*—A probe technique has been employed with a 20-Mev betatron whereby small samples of (γ, n) activities have been produced having average specific activities of 6 mc/g. The method permits advantage to be taken of the small cross-sectional area of the electron beam. Since the cross section for photo-disintegration is about 400 times greater than that for electro-disintegration the strong activities are achieved by inserting a lead target between the electron beam and the sample, so as to provide a concentrated beam of x-rays. $Cu^{63}(\gamma, n)Cu^{62}$ activities so far have been produced in strips of Cu foil 2 mm wide, 1.5 cm long, and 45 mg/cm² thick with strengths in excess of 80 microcuries. Several activated strips were used successively to measure the positron spectrum of Cu^{62} in a 180 degree magnetic spectrometer. The field of the spectrometer was continuously monitored by a null method of comparison with the field in the gap of a permanent magnet, the calibration being obtained with the gamma-rays from Co^{60}. Employing the recent measurements of this radiation by Jenson *et al.* preliminary measurements of the Fermi endpoint of Cu^{62} indicate an upper limit of 2.86 ±0.05 Mev.

* Assisted by the joint program of ONR and AEC.

U2. Low Emission Probability Gamma-Rays.* R. G. FLUHARTY AND MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—Use has been made of the photo thresholds of Be and deuterium, to eliminate high backgrounds due to abundant low energy gamma-rays and allow the detection of rare

γ-rays from Co^{60}, Sc^{46}, Cs^{134}, V^{48}, and K^{42} sources. As previously reported the neutrons are detected in a large solution of calcium permanganate, where the neutrons produce Mn^{56} activity which appears as insoluble $Mn^{56}O_2$ due to the Szilard Chalmers process.

Gamma-rays associated with Co^{60} are found which have energy greater than 1.63 Mev, but less than 2.18 Mev and are hence not cross-over gamma-rays associated with the main transition. They were found present to about 1×10^{-3} percent of the Co^{60} disintegrations. The cross-over γ-ray of 2.5 Mev if present is limited to less than 2.5×10^{-5} percent of the disintegrations. Gamma-rays with energy greater than 1.63 Mev and less than 2.18 Mev were found in a Sc^{46} source in 1.2×10^{-5} percent of the disintegrations, they appear to be associated with the Sc^{46} activity. Gamma-rays with energy between 1.63 Mev and 2.18 Mev were found in a Cs^{134} source in an abundance of 7×10^{-5} percent of the Cs^{134} disintegrations. A source of V^{48} emits gamma-rays of energy between 1.63 and 2.18 Mev in 1 percent of the disintegrations. This activity decays with the characteristic 16 day half-life of V^{48}.

* This work was assisted by the joint program of the ONR and AEC.

U3. Instrumental Errors in the Shape of Beta-Spectra. C. Sharp Cook and George E. Owen, *Washington University.*—The positron spectrum of Cu^{61} is being studied in a 5.7-cm radius of curvature semi-circular magnetic spectrometer using a variety of vacuum chamber sizes and baffle designs. Such changes in the spectrometer are experimentally shown to affect the shape of the spectrum. However, the arrangement giving a spectrum with least deviation from the Fermi theory still results in a spectrum in substantial agreement with that previously published.[1] This work has been assisted by the joint program of the ONR and the AEC.

[1] C. S. Cook and L. M. Langer, Phys. Rev. **74**, 227 (1948).

U4. End Point of the Tritium Beta-Ray Spectrum. E. R. Graves and D. I. Meyer.—A new method has been used to measure the end point of the tritium beta-ray spectrum. The bremsstrahlung produced by tritium beta-rays stopped by the atoms of a heavy element, namely zirconium or tantalum, was counted with a thin end window Geiger counter. Aluminum absorbers were inserted between the source and the counter to measure a counting rate *versus* absorber thickness curve. The analysis of the data is accomplished by trial and error fitting of the absorption curve. Assuming zero mass for the neutrino and a trial end point, a Fermi beta-spectrum is calculated. Using this, an x-ray spectrum is calculated, utilizing $I_\nu d_\nu = CZ(\nu_0-\nu)d$ to give the continuous x-ray spectrum produced by a beta ray of energy $h\nu_0$. The complete x-ray spectrum produced by the beta spectrum is derived by summation of the contributions of each interval of the beta-spectrum. The attenuation of this x-ray spectrum by aluminum is calculated. Small corrections for the variation of counter sensitivity with energy are applied. The end point of the beta-ray spectrum is deduced to be 18.0 kev. The error is estimated at -0.5 kev.

U5. The Beta-Spectrum of Be^{10}. P. R. Bell and J. M. Cassidy, *Oak Ridge National Laboratory.*—The beta-spectrum of Be^{10} has been measured using a scintillation counter. The scintillation "spectrometer" was calibrated with Cs^{137}. The 0.550-Mev beta-ray and 0.626-Mev conversion line were both used. The full width of the conversion line at half maximum was 150 kev for the conditions under which the Be^{10} was measured. The Be^{10} samples (which were separated from a cyclotron target in 1944 by Levinger and Meiners) were moderately thick, 7 mg/cm^2 and 2 mg/cm^2. A Kurie plot of the data is straight above 0.38 Mev and gives an endpoint energy of 0.566 ± 0.010 Mev. Below 0.38 Mev the curve falls below the straight line especially for the thinner source. It is not certain whether this curvature is real. Comparison will be made between the Be^{10} results and those for other substances.

U6. Nitrogen 12. Luis W. Alvarez, *University of California, Berkeley.*—The bombardment of carbon with high energy protons from a linear accelerator yields a radioactive isotope with 12.5 ± 1 millisecond half life, and 16.6 ± 0.2 Mev upper limit positrons. The proton threshold energy is 20.0 ± 0.1 Mev. On energetic grounds, all isotopes but N^{12} may be eliminated as the active substance. On the assumption that it is N^{12}, there is an accurate agreement between the threshold and the upper limit, assuming a p,n reaction. The mass of N^{12} is 12.0228 ± 0.00015, and the beta-transition is allowed. N^{12} is within about 200 kev of being proton unstable. This work was done under the auspices of AEC.

U7. Recoils from the Beta-Decay of Y90. C. W. Sherwin, *University of Illinois.*—A number of very thin sources of Y90 have been studied using a beta-spectrometer to select electron momentum, and using the time of flight method to measure the recoil velocity. A large fraction of all the recoil atoms escape charged which would be impossible if the average source thickness is much in excess of one atomic layer. Measurements using applied accelerating potentials show that the recoil ions have the e/m of singly charged particles of mass 90 ± 8. Any inferences about the neutrino direction are made impossible by the large energy losses of the Zr^+ recoils which appear to have a minimum value of 17 ± 4 ev. Using the latest value of 2.35 Mev for the upper limit of the Y90 beta-spectrum, one should observe recoils up to 48 ev. Actually there are no observable recoils which have a velocity greater than that corresponding to 31 ± 4 ev, but at this value recoils suddenly appear in great numbers (20 times background). There seems to be no really satisfactory explanation of the 17 ev energy loss, although several independent lines of evidence suggest that it is due to the binding energy of the Zr^+ ion to the substrate.

U8. New Radioactive Isotopes of Yttrium and Zirconium. W. E. Scott, B. E. Robertson, and M. L. Pool, *Ohio State University.*—A 3.7 ± 0.1-hour period in yttrium has been obtained by bombardment of $Sr^{84}O$* with 10-Mev deuterons and natural SrO with 5-Mev protons. The $Sr^{84}O$ was enriched to 27.7 percent in Sr^{84}. Characteristic radiations are 2.0 ± 0.1 Mev positrons, strontium x-rays and gamma-rays. Initial intensities indicate that both reactions have large cross sections. This activity must be assigned to Y^{84} or Y^{85}. A 2.0 ± 0.1-hour period in zirconium has been obtained by bombarding $Sr^{84}O$ with 20-Mev alpha-particles. Characteristic radiations are 2.0 ± 0.1-Mev positrons, x-rays and 0.8 ± 0.1-Mev gamma-rays. This activity has been assigned to Zr^{87}. Positron activities associated with the 14-hour and 3.3-day periods of Y^{87} have been found with energies 1.1 ± 0.1 Mev and 0.7 ± 0.1 Mev respectively. Bombardment of Hilger RbCl with alpha-particles has produced a 105-day yttrium activity decaying by emission of a 1.8 ± 0.1-Mev gamma-ray. Relative cross sections for $Rb^{85}(\alpha, 2n):Rb^{85}(\alpha, n):Rb^{87}(\alpha, n)$ are 1:72:14 respectively.

* Supplied by Y-12 Plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. A.E.C., Oak Ridge, Tennessee.

U9. Columbium 90, 96 and Molybdenum 91, 93. D. N. Kundu and M. L. Pool, *Ohio State University.*—A 17-minute Mo activity, readily produced by deuteron bombardment of Mo, is assigned to Mo^{91} by the use of enriched* Mo isotopes. This activity is produced by fast neutron bombardment from Mo^{92} but not from Mo^{94}. A 15.0-hour Cb activity is produced from $Zr^{90}(d, 2n)$ and $Mo^{92}(d, \alpha)$ but not from Zr^{91} with deuterons. It emits 1.19 Mev positrons, 2.03 Mev gamma-rays and a small amount of x-rays and is assigned to Cb^{90}. Further work on the 6.7-hour Mo^{93} has shown that the two groups of charged particles of energies 0.3 and 0.7 Mev are not positrons

but internal conversion electrons from gamma-rays as seen by a beta-ray spectrograph. The first gamma-ray is completely converted but a small amount of the unconverted second gamma-ray has been detected in the lead absorption. Compton electrons checked the value of the hard 1.6 Mev gamma-ray. A long-lived isomer of Mo^{93} is indicated. The half-life and decay characteristics of Cb^{96} given by others are found to be unconfirmed. Instead, a half-life of 23.3-hour from $Zr^{96}(p, n)$ is assigned to Cb^{96} by bombardments on enriched Zr isotopes. This activity decays by emitting 0.67 Mev negative beta-particles and 1.03 Mev gamma-rays.

* Supplied by Y-12 Plant, Carbide and Carbon Chemicals Corporation, through the Isotope Division, U. S. AEC, Oak Ridge, Tennessee.

U10. Silver and Cadmium Activities. JANE R. GUM, LOWELL E. THOMPSON,* AND M. L. POOL, *Ohio State University.*—Pd+α and Cd+n (fast) yield in the Cd fraction a 57-minute activity assigned to Cd^{105}. 1.5-Mev positrons are emitted. Cd^{109} from Ag+d, followed for over 5 years, has a half-life of 470 days. Pd+α also yields this activity. Cd+d and Cd+n (fast) give in the Cd fraction a 5-year activity measured over 3.7 years. 0.45-Mev negative particles are emitted, but no gamma-rays. The relative Pd+α reaction cross sections for Cd^{106}, Cd^{107}, Cd^{109} are 1, 4.5, 970 respectively. Over nine half-lives of Ag^{106} from Rh+α a value of 8.6 days is obtained. Pd+d and Rh+α yield 40-day Ag^{105} as measured by the x-ray activity over seven half-lives. Measurements made over 5.4 years show that Ag^{110} from Pd+d has a half-life of 270 days.

* Now at Army Chemical Center, Maryland.

U11. Nuclear Lifetime for a Quadrupole Transition in Cd^{111}.* MARTIN DEUTSCH AND DONALD T. STEVENSON, *Massachusetts Institute of Technology.*—An excited state of Cd^{111} with half-life $(8\pm1)\times10^{-8}$ sec. has been found in the decay of In^{111}. Delayed electron-electron and gamma-gamma-coincidences were observed using scintillation counters and a five channel delay analyzer. This state seems to be the 0.247 Mev level previously reported.[1] From Segrè's formula one calculates a half-life of 5×10^{-10} sec. for electric quadrupole and 2×10^{-4} sec. for electric octupole gamma-rays of this energy. Probably the transition is electric quadrupole with a matrix element $|M|^2\simeq10^{-2}$. Rose *et al.*[2] calculate a conversion coefficient $\alpha_K\simeq0.05$ for such a transition compared with a measured value[3] of 0.1. Alternatively one might assume that the transition probability for magnetic quadrupole radiation is 2000 times greater than that calculated for electric octupole. This seems unlikely. The conversion coefficient for this case[2] should be 0.16.

* Supported in part by the joint program of the AEC and ONR.
[1] See Seaborg and Perlman, Rev. Mod. Phys. **20**, 585 (1948).
[2] Report privately circulated.
[3] Helmholz *et al.*, Bull. Am. Phys. Soc. **24**, No. 2, 18 (1949).

SATURDAY MORNING AT 10:00

Hall of Government, 1

(E. P. WIGNER presiding)

Theoretical Physics, I

V1. Relativity Corrections for Energy Levels. V. ROJANSKY AND FRANK STERN, *Union College.*—When the perturbing potential $-(E-U)^2/2\ mc^2$ is used in computing relativistic energy corrections, the standard procedure is to take for $(E-U)^2$ the operator K^2, where $K=E-V$, and V is the operator associated with the potential energy U. No compelling reason exists, however, for not interpreting $E-U$ as the kinetic energy operator T, namely, $-(\hbar^2/2m)\Delta^2$. If we take $\frac{1}{4}(K+T)^2$ for $(E-U)^2$ and let $K\psi=T\psi$, we find that for a Coulomb field $[\frac{1}{4}(K+T)^2-K^2]\psi$ equals $[(\hbar^2/2m)V'd/dr]\psi$. This term appears in the small energy form of the Dirac equation and accounts for the shifts of the s levels without affecting other levels. Therefore, the choice of $\frac{1}{4}(K+T)^2$ for $(E-U)^2$ permits us to obtain the standard relativity-and-spin corrections for hydrogenic atoms without recourse to the Dirac equation and without the artifice of ascribing non-zero values to the superficially indeterminate Pauli spin corrections for s states. A more careful reinterpretation of $(E-U)^2$ with the help of Poisson brackets, followed by a perturbation calculation, leads to the same shifts for Coulomb fields as does the use of $\frac{1}{4}(K+T)^2$.

V2. The *K*-Shell Internal Conversion Coefficients.* M. E. ROSE, G. H. GOERTZEL, B. I. SPINRAD, *Oak Ridge National Laboratory;* AND J. HARR AND P. STRONG, *Harvard University.*—The internal conversion coefficients for the K-shell have been computed using Dirac hydrogen-like wave functions. The range of calculation is for $Z=40$ to 96, gamma-ray energy k from 0.3 to 5.0 mc^2 and for multipole orders through 2^5 electric and magnetic. In this range 500 values were obtained, accurate to four significant figures, and an additional 2560 values, accurate to within 2 percent, were obtained by interpolation. Further values in the range can be obtained by linear interpolation of log coefficient against Z and/or log$k$. These values of the conversion coefficients show that the approximate formulas have very limited validity at $Z=40$, and it is planned to extend the computations to smaller Z. Slides showing the behavior of the conversion coefficient as a function of energy and of Z will be shown. Plans are under way to extend these computations (with screening included) to the L-shell.

* Based on work performed for AEC.

V3. Note on Wave Functions in a Magnetic Field. M. H. JOHNSON AND B. A. LIPPMANN, *Naval Research Laboratory.*—Wave functions describing the non-relativistic motion of a charged particle in a homogeneous magnetic field, H_z, can be obtained by factorization (in close analogy to the treatment of the harmonic oscillator), if the kinetic momenta, $\boldsymbol{\pi}=\mathbf{p}-(e/c)\mathbf{A}$, are used as variables. The solutions are $\psi_n=(\pi_x-i\pi_y)^n\psi_0$ where ψ_0 is determined by $(\pi_x+i\pi_y)\psi_0=0$. Solutions, which are also eigenfunctions for the angular momentum parallel to H_z, can only be found for the special vector potential $(-y, x, 0)H_z/2$. A change of this potential by a gauge transformation destroys the constancy of angular momentum. Solutions of the Dirac equation can be written in the form $\psi^i=(c\boldsymbol{\alpha}\cdot\boldsymbol{\pi}+\beta mc^2+E_i)\chi^i$. The spinor χ^i satisfies a second-order equation which splits into separate equations for each spinor component if χ^i is an eigenspinor for σ_z. Application of the same factorization method then leads to solutions of the Dirac equation valid for any gauge.

V4. Bremsstrahlung in Heavy Elements. H. WERGELAND, *Purdue University.*—Following a suggestion of H. Bethe, the matrix elements are calculated with electron waves distorted by a variable phase. The correction is the first term of an asymptotic expansion in powers of the electron wave-length. The differential cross section for the process: electron of wave vector $\mathbf{k}\rightarrow\mathbf{k}'$+light quantum $\mathbf{q}$, is found to be

$$d\sigma=\frac{\alpha^2}{137\pi^2}\left(\frac{\pi\alpha}{\sinh\pi\alpha}\right)^2\cdot qdqd\Omega_{\mathbf{q}}d\Omega_{\mathbf{k}'}$$
$$\times\frac{k}{k'}\left(\frac{1}{\beta^2+M^2}\right)^2\cdot\sum_{\lambda=1}^{2}\Big\{(\mathbf{e}_\lambda\cdot\mathbf{e}_k)^2\Big[1+2\frac{Yk\sin\vartheta}{Z^2}$$
$$+(1+\alpha^2)\frac{Y^2k^2\sin^2\vartheta}{Z^4}\Big]+2(\mathbf{e}_\lambda\cdot\mathbf{e}_k)(\mathbf{e}_\lambda\cdot\mathbf{R})$$
$$\times\Big[\frac{1}{Z}+(1+\alpha^2)\frac{Yk\sin\vartheta}{Z^3}\Big]+(\mathbf{e}_\lambda\cdot\mathbf{R})^2(1+\alpha^2)\frac{1}{Z^2}\Big\}.$$

Here: $1/\beta$=screening radius, $\alpha=Ze^2/\hbar v$, $\vartheta=\sphericalangle(\mathbf{k},\mathbf{k}')$, $\mathbf{M}=\mathbf{k}-\mathbf{k}'-\mathbf{q}=(X,Y,Z)=(\mathbf{R},Z)$.

V5. ThC-C″ Alpha-Transition According to the Water Drop Model of Alpha-Decay.* J. E. GARVEY AND B. T. DARLING, *Ohio State University.*—Following the recent work on the Radium-Radon alpha-transition, calculations according to the proposed model have been made for the ThC-C″ transition. On this model, the most natural choice of vibrational (β) mode and alpha-particle angular momentum (L) would seem to be: $\beta=0$, $L=0$ for α_0; $\beta=1$, $L=1$ for α_1; $\beta=2$, $L=2$ for α_2, α_3, α_4, where the α_i refer to the alpha-groups of ThC-C″. Using the experimental values of the ground state (α_0) partial decay constant and the disintegration energy, we determined two adjustable constants, the nuclear radius (R) and the well depth (D). With these values for R, K, the assigned values for (β) and (L) and the experimental disintegration energies, the intensities were calculated. They were found to be in good agreement with the observed intensities. Of especial interest is the calculated α_1/α_0 intensity ratio which we find >1, as required by experiment. The usual alpha-decay theory achieves this ratio only by allowing the angular momentum associated with α_0 to be several units greater than that associated with α_1.

In view of these results the angular momentum assignments throughout the ThB-ThD system are being reinvestigated.

* B. T. Darling and J. E. Garvey, Bull. Am. Phys. Soc. **24**, 24 (1949).

V6. Closed Shells in Nuclei. MARIA G. MAYER.—The spins of all nuclei of even proton and neutron number are zero, and the magnetic moments of nuclei of odd mass number are consistent with the assumption that they, as well as the nuclear spin, are exclusively due to the odd nucleon.[1] This gives an experimental determination of orbital and total angular momentum for the last odd constituent of the nucleus.[2] The assumption is made that there exists a strong spin-orbit coupling favoring high total angular momenta. The observed orbits and spins are then seen to be in agreement with those of the square well potential. The larger shells of particular stability, namely, of 50, 82, 126 protons or neutrons, are seen to be due to the splitting of the g, h, and i levels, respectively. The high frequency of occurrence of nuclear isomerism in odd mass number nuclei towards the end of a shell is predicted by this model. Agreement with β-decay half-lives is obtained.

[1] Th. Schmidt, Zeits. f. Physik **106**, 358 (1937); H. H. Goldsmith and D. R. Inglis, Brookhaven publication.
[2] E. Feenberg, in press; L. Nordheim, in press.

V7. The Phenomenological Theory of Nuclear Forces. HERMAN FESHBACH, *Massachusetts Institute of Technology.*—The recent analysis of neutron-proton scattering, and the theory of the triton have shown that it is impossible to maintain the charge-independence of nuclear forces if the rectangular well potential is employed for the two body nuclear interaction in the manner described by Rarita and Schwinger. It is possible, however, to obtain (1) charge-independence, (2) the experimental scattering of neutrons by ortho- and para-hydrogen, (3) neutron-proton scattering at moderate energies, (4) the binding energy of H^3, (5) neutron-proton scattering at 90 Mev in addition to the deuteron data, and thermal $n-p$ scattering through the use of a suitable potential. The potential employed is $V(r)=1/3(\tau_1\cdot\tau_2)(\sigma_1\cdot\sigma_2)V_0\{[(1-g/2)+g/2\sigma_1\cdot\sigma_2]\times(\exp-\beta r/\beta r)+\gamma S_{12}(\exp-\tau r/\tau r)\}$. The value of β is taken from ($p-p$) scattering. The value of $(1-2g)V_0$, adjusted to yield the correct thermal $n-p$ cross section, is approximately equal to the $p-p$ value. The relations between γ, τ, and V_0 are obtained from the binding energy and quadrupole moment of H^2. The experimental constant most sensitive to a choice in τ is the binding energy of H^3.

V8. Relativistic Generalization of Phenomenological $n-p$ Interactions. ARMAND SIEGEL, *Massachusetts Institute of Technology.*—A general method of extending currently postulated phenomenological $n-p$ interactions to the relativistic domain has been constructed, after Breit.[1] This method should indicate the relativistic corrections obtainable within a Dirac matrix formalism, for any given non-relativistic interaction. Such corrections may be important for the 90-Mev experiments.[2] One works from a momentum representation of the non-relativistic interaction. This is a Pauli and isotopic spin operator involving the momenta. The momenta are replaced by four-vectors, and the Pauli operators by Dirac operators, in such fashion that one obtains an invariant cross section, reducing to the non-relativistic one. The Dirac operator-Pauli operator correspondence is non-unique, permitting adjustment to experiment. The relativistic corrections to the cross section generated by the Rarita-Schwinger interaction with symmetrical exchange[3] have been computed to order v^2/c^2 in the Born Approximation. The correlation of angular dependence with contribution to total cross section in these does not favor adjustment to experiment. Computations with an adjusted meson-well interaction are in progress.

[1] G. Breit, Phys. Rev. **53**, 153 (1938).
[2] Hadley, Kelly, Leith, Segrè, Wiegand, and York, Phys. Rev. **75**, 351 (1949).
[3] W. Rarita and J. Schwinger, Phys. Rev. **59**, 556 (1941).

V9. Distributions from Resonance Reactions and Angular Correlation Experiments. L. EISENBUD, *Bartol Research Foundation.*—Consider a reaction at resonance described by $l+L\rightarrow J\rightarrow K+k$. (Our symbols designate both the systems in question and their total angular momentum quantum numbers.) The initial state of the system, $l+L$, is an unpolarized plane wave; the polarization of the emitted k particles is not observed. There is a strong formal resemblance between the physical situation described above and that involved in angular correlation experiments. In the latter, the directional correlation between particles l and k (polarizations not measured) from the reactions described by $L\rightarrow l+J$ and $J\rightarrow k+K$ are measured. The initial state L is unpolarized. The angular distribution of the k particles relative to the l particles has the same formal properties in both the correlation and reaction experiments if, in the latter, non-resonance terms are consistently eliminated. As is known,[1] the correlation distribution may always be represented as a polynomial in $\cos^2\theta$ of degree J or smaller. The same statement may be made for resonance reactions if the cross sections at resonance are large by comparison with the background.

C. N. Yang, Phys. Rev. **74**, 764 (1948).

V10. Applications of the Dispersion Formula for Nuclear Reactions. T. TEICHMANN AND E. P. WIGNER, *Princeton University.*—The dispersion formulas for nuclear reactions have been applied to some problems of level widths ($\Gamma_{\lambda s}$) and cross sections. The proportionality[1] of the level spacing (D) to reduced level width ($\gamma_{\lambda s}^2=\Gamma_{\lambda s}/2K_{\lambda s}$, where $K_{\lambda s}$ is the wave number of the outgoing particle) has been derived from a

general sum rule: This derivation shows that $\gamma_{\lambda s}^2$ must be averaged over many levels and also explains the decrease of the ratio $\gamma_{\lambda s}^2/D$ with increasing mass number A. A similar sum rule is obtained for the sum of the reduced widths from one state of the compound nucleus to all states of the final system (i.e., for $\Sigma_s \gamma_{\lambda s}^2$). This rule suggests that the transition probabilities to highly excited states of the product nucleus are smaller than would follow from the statistical model (Schiff). The ratio of the minima to the maxima of the rapidly fluctuating reaction cross sections has been calculated to be of the order Γ^2/D^2. The same quantity for the scattering cross section (and in exceptional cases for the reaction cross section) is of the order Γ^4/D^4. It is shown that the average cross section is smaller than the value obtained for widely separated levels, and the correction is calculated.

Feshbach, Peaslee and Weisskopf, Phys. Rev. 71, 143 (1947).

V11. On the Continuity of the First Derivative in the Wigner-Eisenbud Formalism. J. L. JACKSON, *New York University.*—In the Wigner-Eisenbud approach to nuclear resonance reactions, the wave function of the nuclear system is expanded in the internal region in terms of a set of functions, X_λ, which satisfy the Schrödinger equation of the system and the Hermitian boundary condition, $\text{grad}X_\lambda = 0$, on the surface separating the internal and external regions. Due to this boundary condition, however, there is a question as to the convergence of the series expansion of the first derivative at the surface. The nature of the convergence of the series for the first derivative was investigated and a simple one-dimensional argument is presented, showing that the expansion of the first derivative does indeed converge non-uniformly to the value of the first derivative of the wave function at the boundary.

SATURDAY AFTERNOON AT 2:00

National Academy

(A. C. G. MITCHELL presiding)

Beta- and Gamma-Emitters, II

W1. Radioactive In and Sn. E. C. MALLARY AND M. L. POOL, *Ohio State University.*—Various samples of electromagnetically enriched* cadmium (oxides) received cyclotron irradiation in pairs on opposite sides of a rotating target or individually on a fixed target. $Cd^{106}(\alpha, p)In^{109}$, $Cd^{108}(d, n)In^{109}$, and $Cd^{108}(p, \gamma)In^{109}$ produced a 4.30±0.15-hour activity decaying by 0.70±0.05-Mev positrons, K capture, and γ-rays. $Cd^{106}+d$, and $Cd^{106}+p$ produced in In a 33±2-min. positron activity. $Cd^{106}+\alpha$ produced in Sn a 15-min. positron activity. $Cd^{110} \times (d, n)In^{111}$ produced a measurable amount of 2.84-day positrons. $Cd^{106}+\alpha$ produced in the Sn fraction a 2.0-Mev positron activity which increased after the Sn separation and then decayed with an apparent 4.5-hour half-life. This observation is assumed to be due to the recently reported 4.5-hour K capture in Sn followed by the 72-min, 2.2-Mev positron emission in In. These activities are tentatively assigned to Sn^{108} and In^{108}. Element assignments were assisted by chemical separation.

* Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation through the Isotope Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

W2. Internal Conversion Electrons from Long-Lived Tellurium Isomers. R. D. HILL, *University of Illinois.**—Samples of enriched Te^{122}, Te^{124}, Te^{125}, Te^{126}, Te^{128}, and Te^{130} isotopes were activated by neutrons in the pile at Oak Ridge and then subjected to beta-ray spectrographic analysis. A new isomer of stable Te^{123} was revealed by its converted γ-ray transitions of 88.5 and 159 kev. It is now clear that each odd tellurium isotope (121–131) exists in a long-lived isomeric state, and the following data are given:

Isomer	Te^{121}	Te^{123}	Te^{125}
Half-life	~140 day	~100 day	58 day
γ-Energy (kev)	82,213[1]	88·5,159[1]	109·7,35.5[2]
Isomer	**Te^{127}**	**Te^{129}**	**Te^{131}**
Half-life	90 day	30 day	1.2 day
γ-Energy (kev)	88·5(86)[3]	106(102)[3]	(177)[3]

The most strongly produced isomer is Te^{125}, and an estimate of the slow neutron isotopic capture cross section of Te^{124} for the production of this isomer is ~5 barns. There are also conversion lines of 32.5 and 35 kev which have not yet been assigned to either Te^{121} or Te^{123}.

* Assisted by the joint ONR and AEC programs.
[1] R. D. Hill and J. W. Mihelich, Phys. Rev. **74**, 1874 (1948).
[2] Hill, Scharff-Goldhaber, and Friedlander, Phys. Rev. **75**, 324 (1949).
[3] A. C. Helmholtz, Phys. Rev. **60**, 415 (1941).

W3. Radiations from the 11-Day Neodymium and the 47-Hour Element 61.† C. E. MANDEVILLE AND M. V. SCHERB.†† *Bartol Research Foundation.*—Pure Nd_2O_3, prepared at The Institute for Atomic Research, Iowa State College, was irradiated by slow neutrons for four hours in the Oak Ridge pile. No chemical separations were performed. Some preliminary data will be presented for comment. The visual absorption limit of the 11-day beta-ray spectrum occurs at about 0.7 Mev. The gamma-ray energy is 0.5 Mev by lead absorption. The end point of the 47-hour beta-spectrum is at 0.98 Mev, and these beta-rays are coincident with gamma-rays of energy ~0.2 Mev. The soft gamma-rays are also present on lead absorption curves. Beta-beta-coincidences were observed in the 47-hour activity. These data are in partial agreement with earlier measurements.[1]

† Assisted by the joint program of ONR and the AEC.
†† Now at Princeton University.
[1] Marinsky, Glendenin, and Coryell, J. Am. Chem. Soc. **69**, 2781 (1947).

W4. Disintegration of Cs^{137}.* CHARLES L. PEACOCK, *Indiana University.*—The radiations of Cs^{137} have been studied with a 180-degree spectrometer and a thin window detector under good source and resolution conditions. A single gamma-ray of 0.669 Mev is 12 percent internally converted. The beta-spectrum consists of two groups with end points of 0.521 Mev and 1.19 Mev, respectively, with the latter having a relative abundance of only 5 percent. The shape of the Fermi plot of the low energy group does not indicate an allowed transition since it is distinctly concave towards the energy axis. Although this shape has been predicted, it has not been found previously. We have tried, by using various shape factors,[1] to fit this data. The factor a alone gives a very good straight line, while the other factors, alone or in combinations, do not fit the data. Under G-T rules the factor a alone is contained in the C_{1T} or C_{1A} interactions. This suggests

that, contrary to its long half-life, the transition is first forbidden with $\Delta j = \pm 2$ and a parity change.

* Assisted by the joint program of the ONR and the AEC.
[1] E. J. Konopinski, Rev. Mod. Phys. **15**, 209 (1943).

W5. Shapes of Forbidden Beta-Spectra.* LAWRENCE M. LANGER AND H. CLAY PRICE, JR., *Indiana University.*—Momentum distributions have been investigated for disintegrations in which the *comparative lifetime* (f value) suggests that the transition is empirically forbidden. Measurements were made with high resolution and relatively thin Oak Ridge sources in the 40-cm radius of curvature magnetic spectrometer. The spectra of Y^{91} and Cs^{137} are found to have shapes decidedly different from the allowed distribution. In both cases the Fermi plot approaches the end point with a curvature *towards* the energy axis. Y^{91}, with $f = 4.7 \times 10^8$, would appear to be empirically twice-forbidden. However, the shape of the spectrum is explained exactly as that of a once-forbidden transition involving a spin change of 2 units, with a parity change. This result is confirmation of Feenberg and Hammack's analysis of nuclear shell structure and of the validity of G–T selection rules. The spectra of P^{32}, Re^{186}, and Au^{198} have Fermi plots indistinguishable from a straight line. It is of interest that Au^{198} and Re^{186} have comparative lifetimes and nuclear charges much like those of RaE whose forbidden spectrum has been well established.[1] End points obtained are: P^{32}, 1.696 ± 0.010 Mev; Au^{198}, 0.960 ± 0.005 Mev; Re^{186}, 1.068 ± 0.006 Mev; Y^{91}, 1.537 ± 0.007 Mev; Cs^{137}, 0.51 ± 0.01 Mev.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corporation and by the joint program of the ONR and AEC.
[1] G. J. Neary, Proc. Roy. Soc. **A175** (1940); L. M. Langer, Phys. Rev. **75**, 328 (1949); R. Morrissey and C. S. Wu, Bull. Am. Phys. Soc. **24**, D14 (1948).

W6. The Beta-Spectrum of Tm^{170}. D. SAXON AND J. RICHARDS, *Argonne National Laboratory.*—Using an Oak Ridge purified sample of Tm_2O_3, the β-spectrum of Tm^{170} has been measured in the 180° spectrometer. The Argonne heavy water pile was used to produce the active Tm^{170} by neutron capture. A preliminary value of the half life indicates a single activity of ~120 days. The average source thickness was ≤ 0.1 mg/cm², with a Nylon backing of 0.54 mg/cm². The counter window, also Nylon, was of 5 layers totaling 0.09 mg/cm², made by a process previously reported. The resolution $\Delta H\rho/H\rho$, used was 2 percent. The Kurie plot of the relativistic Fermi function, without screening, is essentially linear; the slight upward trend below 150 kev can be explained by the screening correction alone. Extrapolating, the β-end point is found to be 970 ± 10 kev, checking Boyd and Ketelle closely. At the low energy end of the spectrum are found the K, L, and M internal conversion lines of the single γ-ray. Assuming the γ-ray to follow the β, converting in Yb, the γ-energy is obtained as 85.5 ± 0.5 kev. The coversion coefficients and their ratios are:

E	K	L	M	K/L	L/M.
85.5 kev	3.06%	4.28%	1.68%	0.71	2.55

From the K to L ratio the spin change of the γ-ray is estimated as 2, assuming pure electric multiple radiation.

W7. Nuclear Isomers Produced by Slow Neutron Capture. E. DER MATEOSIAN AND M. GOLDHABER, *Argonne National Laboratory.*—A systematic search for isomers produced by slow neutrons from the heavy water pile has yielded the following new examples:

Isomer	$T_{\frac{1}{2}}$	Energy of internal conversion electrons	Multipole assignment
$_{68}Er$	2.5 sec.	180 kev	2^4
$_{70}Yb$	6 sec.	200 kev	2^4
$_{70}Yb$	50 sec.	10–20 kev	2^3 or 4
$_{74}W$	5.5 sec.	80 kev	2^4

The electron energies were obtained by Al absorption. The 50-sec. Yb isomer emits only L x-rays, the transition energy is therefore 20–30 kev.

W8. Transition Energies of Some Nuclear Isomers. R. L. CALDWELL,* E. DER MATEOSIAN, AND M. GOLDHABER,** *Argonne National Laboratory.*—Accurate values of the transition energy have been measured for a number of isomers using a permanent magnet beta-ray spectrograph, similar to that described by Hill.[1] A special vacuum gate permits the introduction of short lived samples. Some results are summarized in Table I. The estimated error in the energies is ~1 percent.

TABLE I.

Isomer	$T_{\frac{1}{2}}$	Shells from which electrons have been observed	Transition energy kev
Co^{60}	10.7 min.	K, L, M	58.9
Cb^{94}	6.6 min.	K, L, M	41.5
Cs^{134}	3 hr.	K, L, M	128.0
Dy^{165}	1.25 min.	K, L_I, L_{III}, M, N	109.0
Ir^{192}	1.5 min.	L_I, L_{III}, M, N	57.4

* University of Missouri.
** University of Illinois.
[1] R. D. Hill, Phys. Rev. **74**, 78 (1948).

W9. The Radiations of Re^{186} and Re^{188}.* LOUIS A. BEACH, CHARLES L. PEACOCK, AND ROGER G. WILKINSON, *Indiana University.*—The radiations of Re^{186} and Re^{188} have been studied in a small 180° spectrometer. The beta-spectrum of Re^{186} contains three conversion lines of 64.3, 127.8, and 137.5 kev, respectively, corresponding to the K, L, and M lines of a gamma-ray of 138 kev. A Fermi plot of the beta-rays is a straight line and yields an end point of 1.07 Mev. The conversion coefficients of the 138-kev gamma-ray are $\alpha_K = 2.83$ percent, $\alpha_L = 7.03$ percent and $\alpha_M = 1.21$ percent. From the K to L ratio and the curves of Hebb and Nelson[1] the spin change of the γ-ray is found to be 3. The photoelectron spectrum showed lines corresponding to gamma-ray energies of 138 kev and 214 kev. The beta-spectrum of Re^{188} consists of two groups with end points of 2.15 Mev and 0.97 Mev, respectively, with the latter group representing about one-third of the transitions. The photoelectron spectrum indicates several gamma-rays of low intensity that are probably connected with the soft beta-group.

* Assisted by the joint program of the ONR and AEC.
[1] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).

W10. Conversion Electrons of Ra D.* L. CRANBERG** AND J. HALPERN, *University of Pennsylvania.*—Application has been made of the energy calibration of several photographic emulsions previously reported,[1] to a study of the conversion electrons of radium D in a 180° beta-ray spectrograph. Using a thin source of Ra D of high specific activity, the conversion coefficients obtained for the M and N levels relative to the L level are 0.28 and 0.09, respectively. The half-width of the lowest energy line is about 2 kev. Application of this calibration is also being made to a study of the number of conversion electrons produced per disintegration.

* Supported by the joint Program of the ONR and AEC.
** Atomic Energy Commission Fellow.
[1] L. Cranberg and J. Halpern, Bull. Am. Phys. Soc. **24**, 62 (1949).

W11. Correlation between Direction and Polarization of Successive Gamma-Ray Quanta. FRANZ METZGER AND MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—With an improved polarimeter, which will be described, the direction-polarization correlations of Rh^{106} and Sc^{46} have been measured. In the case of rhodium the present results confirm the conclusions drawn from our preliminary measurements.[1] The observation of a direction-polarization correlation in Sc^{46}

indicates that there is no change of parity involved in the transition from the second excited level to the ground state of Ti^{46}. The dependence of the degree of polarization on the angle is consistent with the assumption that the cascade gamma-ray quanta of Sc^{46} are emitted in electric quadrupole transitions between levels with spins 4, 2, and 0. This work was assisted by the joint program of the ONR and the AEC.

M. Deutsch and F. Metzger, Phys. Rev. **74**, 1542 (1948).

W12. Production of Very High Energy Photons by 350-Mev Protons. HERBERT F. YORK, BURTON J. MOYER, AND RUSSELL BJORKLUND, *University of California, Berkeley.*—A study is in progress, by means of a pair counter, of the yield of high energy photons from the target of the 184″ cyclotron during 350-Mev proton bombardment. The energy distribution of the photons shows a broad maximum in the neighborhood of 70 Mev when the target is observed at an angle of 180° (backward) with respect to the proton beam. Observations at an angle of zero degrees (forward) give a maximum above 100 Mev. The cross section per Be nucleus for producing photons between 30 and 105 Mev is of the order of 10^{-27} cm². With 175-Mev protons the spectrum shows no maximum and the yield is about 100 times smaller. Theoretical considerations of bremsstrahlung predict only a small increase in yield in going from 175 to 350 Mev and do not predict a maximum. In establishing the photon nature of this radiation we have checked the recent attenuation measurements of Lawson. Observations will be made for various targets at various angles, and, on the possibility that these gammas are associated with neutral meson decay, search will be made for gamma-gamma-coincidences. The work described in this paper was performed under the auspices of the AEC.

SATURDAY AFTERNOON AT 2:00

Departmental Auditorium

(M. GOLDHABER presiding)

Neutrons

X1. A Rotating-Shutter Time-of-Flight Neutron Spectrometer for the Resonance Region. W. SELOVE, *Argonne National Laboratory.*—A high speed rotating shutter has been built, with characteristics suitable for making time-of-flight neutron cross-section measurements in the resonance region, using a chain reactor as a neutron source. The best resolution available will be about 0.6 microsecond/meter (6 ev at 50, 50 at 200, etc.). This is roughly the same as the best resolution that has been used by the Columbia modulated-cyclotron group. One principal advantage of the new spectrometer is that it is possible to make measurements with relatively small amounts of material; e.g., in measurements on approximately 0.1-gram quantities of the separated isotopes of tungsten it is possible to determine the individual isotope responsible for each of the resonances below 50 ev. The apparatus will be described, and additional results will be given.

X2. Neutron Transmission and Polarization Measurements with an Iron Single Crystal. MERLE BURGY, D. J. HUGHES, AND W. E. WOOLF, *Argonne National Laboratory.*—The transmission of a single iron crystal 2.97 cm in thickness, has been measured as a function of neutron velocity over the range 500 m/sec. to 4000 m/sec. The neutron source was the thermal column of the Argonne heavy water chain reactor. The measurements at various velocity intervals were made with the Argonne velocity selector, and with BeO and graphite filters. The transmission values yield total cross sections which are the sums of the capture and incoherent scattering cross sections, since the Bragg scattering provides a negligible attenuation of the intensity in those velocity intervals in which it occurs. That part of the incoherent scattering due to energy exchange with the iron lattice can be expected to give rise to a polarization of the transmitted beam.[1] This effect has been found, the associated increase in the transmission with magnetization of the single crystal to 11,000 gauss having been measured as a function of velocity. The results found are in agreement with the assumption that most of the incoherent scattering in iron is due to inelastic lattice scattering.

O. Halpern, Phys. Rev. **72**, 260 (1947).

X3. Neutron Yield from 15 Mev Deuterons.* A. J. ALLEN, J. F. NECHAJ, *University of Pittsburgh,* K. H. SUN, AND B. JENNINGS, *Westinghouse Research Laboratory.*—Fast neutron fluxes from a thick beryllium target bombarded by 155 μamp. of deuterons were measured at various angles by a sulphur detector through the reaction $S^{32}(n, p)P^{32}$ [1] and by a fast neutron fission counter using thorium and uranium. Since neutrons from most (d, n) reactions have energies higher than the threshold energies of the detecting reactions, and since the cross sections for (n, p) and (n, f) processes seem to level off at high neutron energies, a constant cross section values (0.3, 0.6, 0.2 barn for the $S^{32}(n, p)$, $U^{233}(n, f)$ and $Th^{232}(n, f)$ respectively) were assumed. The result from both methods was found to be $(0.6 \text{ to } 1.5)\times 10^9$ neutrons/cm²/sec./μamp. at 1.43 cm in front of the target. The angular measurements from 20° through 340° with uniform background of scattered neutrons at 4.4 cm from the target-point will be shown in curves. Preliminary measurements on other monoisotopic elements indicate that the yield decreases with increasing atomic number.

* Partially supported by ONR.

[1] E. D. Klema and A. O. Hanson, Phys. Rev. **73**, 106 (1948).

X4. Neutron Cross Sections at 115 ev and 300 ev. C. T. HIBDON AND C. O. MUEHLHAUSE.—Total neutron cross sections have been measured at the resonance scattering energies of Co(115 ev)[1] and Mn(300 ev)[2]. These materials, in thin foil form, have been used in a 4π annular scattering chamber[1] as neutron scattering detectors. They have been shown to have a resolving power ~15 or 20 when corrected for "potential scattering." Transmission curves for about thirty elements have been determined using detectors of Co, Mn, and C. This information has yielded initial and asymptotic cross sections, σ_i and σ_p respectively, at the Co and Mn energies. Except for large $1/v$ absorbers (e.g. B and Cl) σ_p has been identified as the "potential or minimum scattering cross section," and $\sigma_i > \sigma_p$ with an indication of resonance overlapping with the detector.

[1] S. Harris, A. Langsdorf, and F. Seidl, Phys. Rev. **72**, 866 (1947); Wu *et al.*, Phys. Rev. **71**, 174 (1947).
[2] M. Goldhaber and A. Yalow, Phys. Rev. **69**, 47A (1946); N. Barbre and M. Goldhaber, Phys. Rev. **71**, 141A (1947); F. Seidl, S. Harris and A. Langsdorf, Phys. Rev. **72**, 168A (1947); Rainwater *et al.*, Phys. Rev. **71**, 65 (1947).

X5. Fast Neutron Cross Sections and Nuclear Shell Structure. D. F. SHERMAN, D. J. HUGHES, J. R. WALLACE, *Argonne National Laboratory.*—Radiative capture cross sections for neutrons of effective energy 1 Mev (unmoderated fission neutrons) have already been reported.[1] These early results, consisting of cross sections for 31 isotopes, showed a smooth increase of cross section with atomic weight, A, up to $A=100$, and an approximately constant cross section for higher A's. The only observed exceptions to the general behavior were Ba^{138}, Pb^{208} and Bi^{209} all of which had extremely low cross sections. It is now known[2] that these three isotopes possess filled neutron shells (Ba^{138}, 82 neutrons; Pb^{208} and Bi^{209}, 126 neutrons), and hence would be expected to exhibit a low binding energy for an additional neutron, with a resultant high level spacing and small neutron capture cross section. In order to test the reality of shell structure the cross sections of Xe^{136}, La^{139}, Pr^{141} (82 neutrons), and Kr^{86}, Rb^{87}, Sr^{88} and Y^{89} (50 neutrons), have been measured. These isotopes all show exceptionally low cross sections, verifying the existence of stable shells at 50 and 82 neutrons.

[1] Hughes, Spatz, and Goldstein, Phys. Rev. **70**, 106A (1946); Phys. Rev. (in press).
[2] M. Mayer, Phys. Rev. **74**, 235 (1948).

X6. Total Cross Section of Carbon and Hydrogen for Fast Neutrons.* E. E. LAMPI, G. FREIER, AND J. H. WILLIAMS, *University of Minnesota.*—The total cross section of neutrons scattered by carbon and hydrogen has been measured in the energy range 0.8 Mev to 1.6 Mev by determining the transmission of graphite and polythene scatterers. A thin lithium target was used with the Minnesota Van de Graaff generator to produce neutrons of discrete energies each having an energy spread of approximately 15 kev. The geometrical corrections were determined by measuring the cross section as a function of the area of the scatterer. The corrected cross section was calculated by a linear extrapolation of the cross section *vs.* area curve to zero area of the scatterer. Measurements of the cross section as a function of the scatterer thickness eliminated errors due to multiple scattering. The results were further checked by increasing the distance from the scatterer to the detector by 50 percent. Preliminary results are tabulated below.

Neutron energy in Mev	Carbon cross section in barns	Hydrogen cross section in barns
0.798	2.82	4.70 ± 0.04
1.078	2.54	4.06 ± 0.03
1.340	2.19	3.63 ± 0.04
1.578	2.00	3.33 ± 0.02

* This research was supported in part by ONR.

X7. Small Angle Scattering of Neutrons. D. MENEGHETTI, *Argonne National Laboratory.*—During neutron cross section studies of powdered crystalline CaO and ZnO, with the mechanical velocity selector, large scattering components were observed in the region from 0.001 to 0.003 ev. By moving the samples closer to the counter, the geometry was changed to include in the measurement neutrons scattered at small angles and the resulting cross sections decreased. The ratio of the geometry change to the cross section change indicated small angle scattering. Subsequent experiments showed that powders and pressed powders scatter neutrons at small angles; single crystals, solids consisting of large crystals, and solid metals do not exhibit small angle scattering. The angular distribution of the scattered neutrons was found to be Gaussian. The half-widths were found to vary directly as the square of the neutron wave-length and as the square root of the sample thickness. In general the results can be accounted for by a theory based on that for refraction of x-rays by finely divided materials.

X8. Neutron Resonance Scattering by W^{186}. S. HARRIS AND C. O. MUEHLHAUSE.—Lowry and Goldhaber[1] have found a resonance activation integral for W^{186} at 18 ev[2] of 446*b*, and accompanying this comparable resonance scattering. Using a 4π-annular scattering chamber[3] we have investigated the epicadmium neutron scattering of normal and enriched W isotopes and found large resonance scattering associated with W^{186}. A boron absorption analysis of the resonantly scattered neutrons has yielded a value of ~15 ev for the resonance energy. The total cross section and the scattering cross section for self indication have been measured for W^{186} and found to be ~16,000*b* and ~11,000*b* respectively. Also the scattering resonance integral by comparison with carbon has been determined for W^{186} and found to be 1100*b*. The latter value, 1100*b*, compared with the 446*b* activation integral indicates that at the 18 ev resonance ~70 percent of the neutrons are scattered and ~30 percent are captured. This is also indicated by the self detected cross sections. Other figures of interest to be compared with these are: Mn (300 ev): 95 percent scattering, 5 percent capture; Au (4.8 ev): 10 percent scattering, 90 percent capture.

[1] L. Lowry and M. Goldhaber, University of Illinois, unpublished (1948).
[2] Havens *et al.*, Phys. Rev. **71**, 165 (1947).
[3] S. Harris, A. Langsdorf, and F. Seidl, Phys. Rev. **72**, 866 (1947).

X9. Widths of Neutron Resonances. L. L. LOWRY* AND M. GOLDHABER, *University of Illinois.*—Resonance integrals $\rho=\int_{\sim 0.5\text{ ev}}^{\infty}\sigma_{cap}(dE/E)$, radiation widths Γ_γ, and neutron widths $g\Gamma_n$ have been measured for various nuclei. They are tabulated, uncorrected for Doppler broadening, in the following order: Resonance energy E_0 (ev), Γ_γ (ev), $g\Gamma_n(10^{-3}$ ev) and $\rho(10^{-24}$ cm^2). Au^{197} was used as a standard and the following constants assumed for it: $E_0=4.8$ ev, $\Gamma_\gamma=0.15$ ev and $g\Gamma_n=0.0079$ ev. Where more than one level was present, the lowest was isolated by the "double filter" method,[1] except for Re^{187}, where the results depend on the assumption that a single level is responsible for most of the activity.

As^{75}	Br^{79}	Rh^{103}	Pd^{108}	Ag^{107}	Ag^{109}	W^{186}	Re^{187}	Ir^{193}
—	—	1.28	24	—	5.1	18	(~27)	1.29
—	—	0.14	0.14	—	0.12	0.12	(~3)	0.10
—	—	0.4	49	—	6	39	(~90)	0.5
70	168	790	316	161	1080	446	454	1424

For Pd^{108} and W^{186}, where the resonances are very high, Γ_γ and Γ_n are of the same order.[2]

* Now at Los Alamos Scientific Laboratory.
[1] A. A. Yalow and M. Goldhaber, Phys. Rev. **68**, 99 (1945).
[2] See abstract by S. Harris and C. O. Muehlhause.

X10. Resonance Neutron Activation of "Even-Even" Nuclei. A. W. SUNYAR AND M. GOLDHABER, *University of Illinois.**—Capture resonance integrals have been determined for the following capturing nuclei of the "even-even" type: Ni^{64}, Zn^{68}, Ge^{74}, Se^{80}, Zr^{96}, Mo^{100}, Ru^{104}, Pd^{110}, Cd^{116}, Sn^{122}, Sn^{124}, Ba^{138}, Sm^{152}, Os^{190}, Pt^{198}, Hg^{204} and Pb^{208}. The resonance integrals are found to be $\lesssim 10\times10^{-24}$ cm^2 with two exceptions. For Sm^{152} we find 2400×10^{-24} cm^2 and for Pt^{198} 77×10^{-24} cm^2. Sm^{152} has the highest resonance we have found, with a maximum cross section $>100{,}000\times10^{-24}$ cm^2. For Sm^{152} the radiation width and neutron width are of the same order of magnitude, each ~0.1 ev. It appears that "even-even" nuclei differ from "odd-even" nuclei (see preceding abstract) in having larger Γ_n and smaller level density. The natural line width for the resonance level in Pd^{108} has been determined by a variation of the usual Doppler effect method. A thick "self-absorber" removed neutrons within a few half-widths of the resonance maximum. The activity was measured at two detector temperatures. The natural width determined from the activity ratio is ~0.20 ev.

* Supported jointly by ONR and AEC.

SATURDAY AFTERNOON AT 2:00

Department of Commerce

(L. MARTON presiding)

Electron Physics

Y1. A Dynamic System for Secondary Electron Emission Measurements at High Temperatures. L. J. RUEGER AND F. C. TODD, *Battelle Memorial Institute.*—For a survey of the secondary electron emission of materials at high temperatures, equipment has been constructed that employs interchangeable targets in a dynamic vacuum system. To measure the secondary electron emission from metals, semiconductors and insulators under identical conditions and without the accumulation of charges on the surfaces, a pulse technique is employed. The energy of the primary beam is varied from 100 to 2000 volts, and the duty cycle can be varied from 1 microsecond on and 5000 microseconds off to 10 microseconds on and 240 microseconds off. By variation of the duty cycle, it is easy to demonstrate that accumulated surface charges do not affect the measurements. The equipment was checked by measurements on molybdenum targets; no temperature dependence was observed and excellent agreement was obtained with published results. Surfaces were first outgassed at 1100°C and gave very reproducible measurements for surface temperatures down to 600°C before adsorbed gases were observed. This paper is based on work performed on U. S. Air Force Contract.

Y2. Secondary Electron Emission from Oxides at High Temperatures. F. C. TODD AND L. J. RUEGER, *Battelle Memorial Institute.*—The secondary electron emission at high temperature has been reported by several authors for barium-strontium coated cathodes.[1,2] Comparable data on other oxides have been obtained with pulse techniques. To avoid surface films, all surfaces were first held at 1100°C for about 15 minutes. With filament-heated molybdenum targets of the same secondary emission, the secondary electron emission of thin films of thorium oxide, lanthanum oxide, uranium oxide, and manganese oxide have been measured in the temperature range from 800° to 1100°C. The resistivity of these same oxides has been measured over a larger temperature range for comparison with the secondary emission. The secondary electron emission from an oxide often shows a peak, or minimum in this temperature range. This paper is based on work performed on U. S. Air Force Contract.

[1] J. B. Johnson, Phys. Rev. **73**, 1058 (1948).
[2] M. A. Pomerantz, Phys. Rev. **70**, 33 (1946).

Y3. An Interpretation of Secondary Electron Emission Data for Homogeneous Solids. E. J. STERNGLASS, *Naval Ordnance Laboratory.*—The secondary electron emission ratios obtained by other investigators are corrected for the high energy, back-scattered electrons using data by Palluel.[1] Curves showing the relationship between the corrected ratios (Δ) and the energy (V) of the primary electrons are grouped according to the principal quantum number n. The initial slopes s of these curves approach the same limiting value for elements having the same n. $1/s$ is found to be equal to the average amount of energy Φ taken from the primary electron per low energy secondary electron formed, and it can be expressed as $12\exp(n/2)$. If Δ is assumed to be equal to the product of the total number of secondaries formed in the solid, per primary electron, times an escape probability $F(V)$, it can be shown from existing data that $F(V)$ decreases with increasing V in an exponential manner. One then arrives at the following useful relationship $\Delta=(AV/\Phi)\exp -kV^{\frac{1}{2}}$, where A and K are empirical constants.

[1] P. Palluel, Comptes Rendus **224**, 1492 (1947).

Y4. Measurement of Probability-Amplitude Distributions. P. S. JASTRUM.—Amplitude distributions for either periodic or randomly varying real functions of one variable can be measured directly by use of a cathode-ray oscilloscope and a phototube. The function, expressed in the form of a time-dependent voltage, is impressed on the vertical deflection plates, and a small section of the screen, selected by a horizontal slit, is viewed by a phototube. The phototube current is proportional to the brightness of the screen at the position of the slit, which, under appropriate conditions, is in turn proportional to the amplitude density of the applied signal at the corresponding voltage. A bias voltage impressed on the vertical plates permits the zero-voltage point to be shifted so that the slit effectively scans all parts of the signal, giving the density distribution as a function of amplitude. The method has been applied to functions consisting of random noise. Distributions have been obtained, for example, of noise passed successively through a bandpass filter, a non-linear element (quadratic or linear rectifier), and a low pass filter that introduces various degrees of frequency distortion. The distributions measured for the quadratic rectifier agree closely with those predicted by Kac and Siegert.

Y5. Noise Characteristics of Dry Cells.* B. R. RUSSELL AND P. H. MILLER, JR., *University of Pennsylvania.*—The fluctuation in current through a commercial dry cell (such as a Burgess xx45) when connected to a loading network have been measured at room temperature in a noise spectrum analyser[1] covering the frequency range from 10^2 to 5×10^5 c.p.s. The noise is found to vary as $^{-1.1}$, and the magnitude of the noise depends on the age and type of battery and the current drawn. A typical order of magnitude for a 45 volt battery is 10^{-13} volts^2/cycle at 1000 c.p.s. where the total resistance in the circuit is 5000 ohm and the noise voltage is observed across 1000 ohms. In some batteries the noise is a maximum when the current drawn is about 10 mils. By using several loading networks with different dependence of impedance upon frequency, the noise appears to be a fluctuation in e.m.f. rather than a varying contact resistance.

* This work was supported by Bureau of Ships, U. S. Navy.
[1] Bull. Am. Phys. Soc. **24**, No. 3, Paper F6 (1949).

Y6. Measurements of Positive Ion-Electron Recombination.* MANFRED A. BIONDI AND SANBORN C. BROWN, *Massachusetts Institute of Technology.*—A microwave method of observing the removal of electrons from initially ionized gases has been developed.[1] A pulsed electrodeless discharge is used, and the decay of electron density is measured after the ionizing field is removed. The method has been applied to studies of positive ion-electron recombination in helium, neon, argon, and oxygen. The pressure range studied is 1–30 mm Hg, and the average energy of the ions and electrons is varied from 0.01 to 0.05 electron volt. The values of the recombination coefficient for these gases are in the range 10^{-8} to 10^{-6} (cc/ion-sec.) and are much larger than values previously reported. The recombination is of two types; one type is independent of pressure and energy over the range studied while the other depends strongly on pressure and energy. The recombination coefficients have been measured as functions of pressure and energy.

* This work has been supported in part by the Signal Corps, the Air Materiel Command and ONR.
[1] Massachusetts Institute of Technology, Research Laboratory of Electronics, Technical Report No. 66.

Y7. Ionization of Neon by Atomic Projectiles of Neon.* JOHN H. MARTIN, *Washington University.*—A study was made of the ionization of neon gas when bombarded with neon ions and neon atoms that have kinetic energies ranging from 25 to 1000 ev. An electronic space-charged type of positive ion detector was used to observe the ionization. The onset of ionization by positive ions was seen to occur at about 43 ev, which is the theoretical minimum energy that the projectile can have. Ionization by an exchange process was observed to occur at energies as low as 25 ev. A plot of the cross section for ionization by collision against the energy of the ionic projectile displayed well-defined peaks at 50, 140, 200, and 300 ev. Above 300 ev a fairly rapid drop of the cross section was observed. The onset of ionization by neon atoms was seen to occur at about 120 ev. A plot of the cross section for this process against projectile energy displayed a smooth rise to a maximum at 700 ev, then a rather rapid decline. Arguments can be presented to explain only a part of the characteristics of these curves.

* Assisted by the joint program of the ONR and the AEC.

Y8. Electric Current Transients through Human Tissue and Skin. JOHN W. MOORE, *Medical College of Virginia.*—Current transients produced by the application of rectangular voltage waves to electrodes on the human body are presented on a large oscillograph screen and photographed for analysis. When the steady-state current is subtracted from the overshooting transient, the semilog plot of the net current *vs.* time did not give a straight line as would be expected from models (consisting of a 3 unit condenser and resistor network) developed by workers using frequency response data. The results tend to agree with Hozowa[1] who obtained with a ballistic galvanometer, the point-by-point shape of the transient. He obtained a semilog plot which deviated from a straight line toward the end of the transient. This was interpreted as a variation in one of the model elements (condenser) with time. However, the present work indicated a double exponential was involved. A network of two RC's was able to give the same type current transient as observed through the human body. Although the steady state current, corresponding to the d.c. resistance varies widely for different subjects and conditions, the semilog plots gave characteristic slopes.

[1] S. Hozowa, Arch. f. d. ges. Physiol. **219**, 111 (1928).

SATURDAY AFTERNOON AT 2:00

Hall of Government, 1

(I. I. RABI presiding)

Theoretical Physics, II

Z1. Meson Production in a Photonuclear Collision. MELVIN LAX, *Syracuse University* AND H. FESHBACH, *Massachusetts Institute of Technology.*—The problem of meson production in a photo-nuclear collision, treated by Hamilton and Peng* is generalized to cover the case of a struck nucleus. An upper limit to the cross section is obtained by using the closure rule, i.e. by including in the cross-section calculation some final states which are not energetically permissible. This upper limit σ' will be a good approximation to the true cross section well above threshold where the energetically possible final states make the most important contribution to the closure sum. σ' splits into an incoherent and a coherent part. For positive meson production the incoherent part is essentially Z times the cross section for a photon proton collision. This result is multiplied by a (form) factor, not much less than unity which favors wide-angle production of mesons. The incoherent part of the cross section is evaluated approximately and shown to be of order unity rather than Z. The physical basis of this result is that a struck nucleus changes its nature on emitting a meson. Except near threshold, the coherent contribution may be neglected relative to the incoherent.

* Proc. Roy. Irish Acad. **1A**, 197 (1944).

Z2. Creation of Mesons by High Energy Nucleons.* E. STRICK, *Purdue University.*—Using the scalar meson theory, Nordheim and Nordheim[1] have calculated, using standard third order perturbation theory, the cross section for the production of mesons by high energy nucleons. Wang,[2] however, has pointed out that Nordheim and Nordheim started from a wrong expression for the transition probabilities. Using the correct expression, it is easily possible to calculate the cross section σ for scalar mesons, and the final result is given by the formula

$$\sigma = 4A(g^2/\hbar c)^2(M/\mu)^2(\hbar c/E_0)^2 \log(M/\mu),$$

where E_0 is the energy of the impinging nucleon and A the atomic weight of the target nucleus. This formula is only valid in the extreme relativistic region, and differs from Nordheim and Nordheim's result only by a numerical factor of the order of magnitude 2.

* Supported in part by a contract with ONR.
[1] L. W. Nordheim and G. Nordheim, Phys. Rev. **54**, 254 (1938).
[2] F. S. Wang, Zeits. f. Physik **115**, 431 (1940).

Z3. Fourth-Order Interaction between Nucleons in the Pseudoscalar Meson Theory. H. A. BETHE, *Cornell University.*—In the pseudoscalar meson theory with pseudoscalar coupling, the ordinary (f^2) interaction between nucleons is weak because it involves the γ_5 operator for each nucleon which is small non-relativistically. It has been shown that therefore $f^2/\hbar c$ must be assumed very large (about 40). The interaction of order f^4 may, in this special case, be expected to be larger than the f^2 interaction: In this case, *two* mesons are exchanged between the two nucleons; therefore the operator γ_5^2 is involved for each nucleon which has the value 1. Calculation shows that indeed $f^2/\hbar c$ now needs to be only about 4 to explain the binding of the deuteron. Going to still higher orders will not give a similar further increase of the interaction. The f^4 interaction automatically gives forces between like and unlike particles of about equal magnitude, even if only charged mesons are assumed. However, the forces are ordinary, spin-independent forces and increase as $1/r^3$ at small distances; only in the relativistic region is the behavior reduced to $1/r$. All these results are contrary to observation, but some of them may still be changed by radiative corrections which must be large because of the still large value of $f^2/\hbar c$.

Z4. Interaction Representation for Mesons. FREDERIK J. BELINFANTE, *Purdue University.*—Authors using supermany-time methods for mesons have avoided incorporating inter-

action terms in whatever *identities* (field equations without $\partial/\partial t$) hold between field co-ordinates $q(x)$. Usually this is possible only after needless complication of the theory by Stueckelberg's introduction of auxiliary conditions. This complication at first seems unavoidable, as simple transformation to interaction representation ("R-transformation") leaves identities unchanged, thus not eliminating interactions there. Due to derivatives of δ-functions in the commutation relations, however, the R-transformed $q(x)$ will depend on the slope through x of the space-like surface σ used for the R-transformation. The R-transformed are made simple point-functions $q^\circ(x)$ again by taking σ at x perpendicular to the time axis. Then the Lorentz transformation of $q^\circ(x)$ will differ from that of $q(x)$. Thence new variables $Q^\circ(x)$ expressible in terms of $q^\circ(x)$ must be introduced as to restore proper tensor behaviour of the $Q^\circ(x)$. This done, the new $Q^\circ(x)$ satisfy *automatically* field equations (including identities) without interaction and the proper relativistic commutation relations. Thus auxiliary conditions are avoided, while the theory is essentially simplified. A neutral vector-meson field with only vector interaction will be discussed as an example.

Z5. On the Classical Theory of the Electron. ALFRED LANDÉ, *Ohio State University.*—The Lorentz force equals the decrease rate of the field momentum, and must therefore be balanced by an increase of mechanical momentum. In a purely unitary field theory which denies energy and momentum of non-electromagnetic origin, the electromagnetic forces and stresses would remain unbalanced, and the field theory would become an empty scheme. The electron must have mechanical mass, surrounded by a field diverging from the charge e. It is possible to build an invariant theory of the electron on the assumption that, although the Lorentz force density is not balanced in every charged volume element by a mechanical momentum increase, yet the total Lorentz force equals the momentum increase of the *mechanical mass* thought in the center of the charge e. The density of the charge may decrease exponentially from the center so as to produce a certain radius. Field and charge distribution then are controlled only by the Maxwell equations, and the motion of the center by relativistic mechanics. Difficulties arise, in case of several electrons, when their charges overlap.

Z6. Invariant Theoretical Determination of Position Operators. T. D. NEWTON AND E. P. WIGNER, *Princeton University.*—The representations of the inhomogeneous Lorentz group provide a listing of all classes of equivalent wave equations of a free particle. Thus the requirement of relativistic invariance gives all equations of motion of quantum mechanics. However, the formalism remains largely empty because the form of only those operators is automatically determined which correspond to total linear and angular momenta. We have attempted to find criteria determining other operators, particularly those corresponding to position. As a first step we sought the wave functions describing a particle localized at a given time t, at a point P. The linear manifold, S_0, of functions localized at the origin for time $t=0$ is defined by certain regularity conditions and two further requirements; (a) that S_0 be invariant under spatial rotations about the origin and space and time reflections; and (b) that a displacement shall make a function of S_0 orthogonal to any undisplaced function of S_0. These axioms uniquely determine S_0, and hence the position operators, for any type of particle of non-zero mass, and of energy of one sign only. The same is true for particles of zero mass and zero or infinite spin. There are two insignificantly different operators in case of spin $\frac{1}{2}$, zero mass. No position operators for larger finite spin, and zero mass, e.g. for the Maxwell equations, can be defined.

Z7. Covariant Field Theories.* PETER G. BERGMANN AND JOHANNA H. M. BRUNINGS, *Syracuse University.*—In an attempt to quantize a consistently covariant field theory, the program outlined in an earlier paper[1] has been pursued further. If the Lagrangian is to be an integral extended only over the nonsingular portions of the field, excluding any singularities (particles), it is useful to introduce an alternative set of coordinates u^s, t, as variables of integration, in terms of which the motions of the particles can be prescribed arbitrarily, even before the field equations are integrated. The original coordinates x^p, including any particle coordinates, then become formally field variables, and their canonical conjugates are the energy and momentum densities. This procedure has some similarity with proposals by Weiss.[2] Since the momenta are not algebraically independent of each other, a function of the field variables and their first derivatives will not be a "dynamical variable" (a function of the canonical coordinates only) unless it satisfies certain differential conditions.

* Assisted by ONR.
[1] Peter G. Bergmann, Phys. Rev. **75**, 680 (1949).
[2] Proc. Roy. Soc. **A156**, 192 (1936), **A169**, 102, 119 (1938).

Z8. Operator Matrices for Relations of Space and Time Intervals. RICHARD SCHLEGEL, *Michigan State College.*—The relations between space and time intervals of a physical displacement can be represented by a matrix which in operation on the vector of a displacement in one dimension gives the associated intervals in other dimensions. Such matrices S and T for pure space and time displacements, respectively, in either a rest system or in one related thereto by a Lorentz transformation, satisfy the equations $ST=T$, $TS=S$, $S^n=S$, $T^n=T$, where n is a positive integer. These relations remove ambiguity from the definition of the operator matrix. Application is made by contrasting the space-time characteristics of observations of particle and wave-properties, and by exhibiting the time interval that is associated with the spatial extension of a particle wave.

Z9. Basic Electromagnetic Theory and the Correspondence Principle.* HERMAN M. SCHWARTZ, *Brookhaven National Laboratory.*—The first part of the paper is concerned with an examination of the attempts to remove the divergence difficulties of present quantum electrodynamics by superposing quantization upon a suitably constructed divergence-free classical model. It is concluded that this extrapolation of Bohr's correspondence principle is not justified. It is suggested that a more reasonable starting point appears at present to be the assumption that the results and concepts of present quantized electromagnetic field theory will appear as a suitable limiting case in the complete theory of the future. The second part of the paper is devoted to a discussion of preliminary calculations, aiming to develop the consequences of the hypothesis that present electromagnetic theory is a limiting case in the sense that it involves continuous space-time description, and that such description is inapplicable for instance, to the discussion of structural properties of elementary particles. The modification proposed cannot be explained rationally in conventional space-time language any more than pure quantum mechanical effects can be explained rationally in the language of Newtonian mechanics. Thus, for instance, one would have to say that an electron has simultaneously properties of a point and also of a rigid extended structure.

* Research carried out at Brookhaven National Laboratory under the auspices of the AEC.

Z10. The Approximate Solution of Certain Boundary Value Problems Involving Moving Boundaries. HOWARD REISS AND VICTOR K. LA MER, *Department of Chemistry, Columbia University.*—A theory of the formation and growth of monodisperse aerosols and hydrosols has been developed on the basis of diffusion theory. Such diffusion problems as the formation or evaporation of small particles are complicated by either the growth or shrinkage of the boundary surfaces. In order to re-

solve such problems, an approximate method has been utilized which depends upon the condition that the flux of diffusing material through any surface in the diffusion field must far exceed the rate of change of concentration of diffusing material on that surface. A boundary condition is formulated for an impermeable shell which is in harmony with the approximate viewpoint. The accuracy of this approximation is measured by applying to cases which involve stationary boundaries where the rigorous solution is available. The method is then utilized for the solution of two crucial problems, involving moving boundaries, which arise in the theory of the growth of monodisperse aerosols and hydrosols. Data on the growth of sulfur sols (Zaiser-La Mer, J. Coll. Sci. **3**, 571 (1948)), computed in this manner, are compared with those obtained by means of light scattering experiments.

Z11. On the Uncertainty Principle. GERTRUDE SCHWARZMANN.—Replacing the electroscope in A. J. Dempster's mass spectograph by a nickel crystal provides an apparatus for testing the validity of the uncertainty principle. Electrons or protons falling through an electric field of known intensity fall with known velocity through slit S_1 into a transversal magnetic field of such strength that they describe a semicircle, its diameter the distance between S_1 and S_2, then fall with unaltered velocity through S_2 upon the nickel target. The measure of agreement between the observed wave-length and its theoretical value obtained in this experiment should be the same as that obtained in experiments performed on undeflected beams notwithstanding the fact that observations on deflected beams measure wave-length and momentum of materiel entities subsequently to an exact determination of their position. This experiment might be regarded as testing the admissibility of previously* outlined concepts of particles, and particle waves, and their interrelation, these concepts requiring that the entities of matter more strictly obey the laws of classical physics than agrees with their current interpretation.

* Phys. Rev. **72**, 154, 536, 744; **73**, 1273, 1274 (1948).

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